LS-DYNA
EXAMPLES MANUAL

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LIVERMORE SOFTWARE
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Introduction

This is an assembly of example problems provided by a number of resources. The resources and histories are documented in the acknowledgment and reference sections. Users are encouraged to submit examples which will facilitate the education of LS-DYNA users.

October 1997 Modifications

- All examples were documented and re-organized for clarity.
- All examples ran successfully using LS-DYNA version 940 on a Sun SPARC 10 workstation.
- Many examples required changes to make them work. Descriptions of the examples were updated to reflect the examples as they are as of this date.
- All graphics in this edition have been replaced with newly created results using LS-TAURUS on the Sun SPARC 10 workstation.
- Many new examples were added to the manual.
- The examples are now strictly in keyword format. References to ingrid and structured format have been removed for they are no longer consistent with these examples.
- Naming Conventions for the examples have been changed as described below.

Naming Convention

The naming convention for the input decks is: keyword.description.k Keyword defines the major keyword used within the example. Description defines either the action or the physical content of the problem. The ".k" on the end of the filename signifies that the file is a keyword format LS-DYNA input file.

LS-DYNA Manual Section: *AIRBAG_SIMPLE_AIRBAG_MODEL

Additional Sections:

*CONTACT_NODES_TO_SURFACE
*RIGIDWALL_PLANAR

Example: Airbag Deploys into Cylinder

Filename: airbag.deploy.k

Description:

An airbag inflates below a rigid cylinder, causing the cylinder to fly into the air.

Model:

The volume pressure relationships is defined by the Simple Airbag Model for control volumes. The bag inflates through the flow of mass into the bag.

Input:

The control volume defines the thermodynamic relationship for the gas in terms of parameters such as heat capacity, gas temperature, incoming mass, and outgoing mass (*AIRBAG_SIMPLE_AIRBAG_MODEL). A rigidwall is used below the airbag to act as ground (*RIGIDWALL_PLANAR). A ground is displayed using rigid shell elements, but is used only for visualization purposes. The contact between the airbag and the cylinder is automatically generated by part id (*CONTACT_NODES_TO_SURFACE).

Results:

The plots show the bag expanding. The ASCII file abstat contains information on the computed pressure, volume, mass flow and internal energy of the control volume (*DATABASE_ABSTAT).

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Airbag and Structure
$
$  LSTC Example
$
$  Last Modified: August 29, 1997
$
$  Airbag with a cylinder on top, deploys and pushes the cylinder into the air.
$
$  Airbag is approximately 19 x 25 inches, with 0.015 in thickness
$
$
$   Units: lbf-s^2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 3.000E-02
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 5.000E-04
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt       lcdt
    999999
$
$
*DATABASE_ABSTAT
$       dt
 2.000E-04
$
*DATABASE_GLSTAT
$       dt
 2.000E-04
$
$
*DATABASE_MATSUM
$       dt
 2.000E-04
```

```
$
*DATABASE_RCFORC
$       dt
 2.000E-04
$
*DATABASE_RBDOUT
$       dt
 2.000E-04
$
*DATABASE_RWFORC
$       dt
 2.000E-04
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Airbag
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*AIRBAG_SIMPLE_AIRBAG_MODEL
$      sid    sidtyp      rbid      vsca      psca      vini       mwd      spsf
         1         1
$
$       cv        cp         t      lcid        mu         a        pe        ro
 1.736E+03 2.430E+03 1.200E+03         1 7.000E-01 0.000E+00 1.470E+01 3.821E-06
$
$      lou

$
*SET_PART_LIST
$      sid       da1       da2       da3       da4
         1
$
$     pid1      pid2      pid3      pid4      pid5      pid6      pid7      pid8
         3
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$           abscissa           ordinate
           0.000E+00           0.000E+00
           3.200E-02           2.600E+01
           4.500E-02           6.000E-01
           8.000E-02           1.000E-01
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigid Walls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Ground
$
*RIGIDWALL_PLANAR
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$     nsid    nsidex     boxid
         0         0         0
$       xt        yt        zt        xh        yh        zh      fric
       0.0       0.0       0.0       0.0       1.0       0.0       0.5
$
```

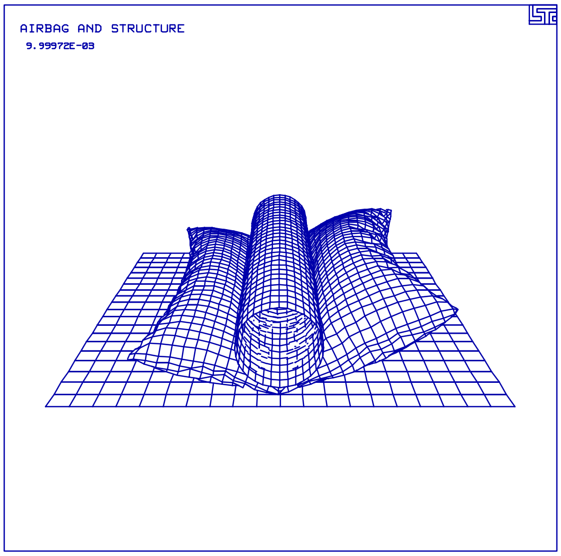
```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Contact between the airbag and the cylinder.
$
*CONTACT_NODES_TO_SURFACE
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         2         3         3                             1         1
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
       0.5       0.5
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
    1.0000   0.06667
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*PART
 Plate - Rigid - Fixed (for viewing)
$      pid       sid       mid     eosid      hgid    adpopt
         1         1         1         0         0         0
$
*PART
 Cylinder - Rigid
$      pid       sid       mid     eosid      hgid    adpopt
         2         1         2         0         0         0
$
*PART
 Airbag - Fabric
$      pid       sid       mid     eosid      hgid    adpopt
         3         2         3         0         0         0
$
$
$$$$$$  Materials
$
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         1   7.84e-4  30.00e+6      0.30
$
$      cmo      con1      con2
         1         7         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2   1.96e-4  30.00e+6      0.30
$
$      cmo      con1      con2
```

```
$
$   lco/a1        a2        a3        v1        v2        v3

$
$
*MAT_FABRIC
$      mid        ro        ea        eb        ec      prba      prca      prcb
         3   1.00e-4   2.00e+6   2.00e+6   2.00e+6      0.35      0.35      0.35
$
$      gab       gbc       gca       gse        el       prl    lratio      damp
   1.53e+6   1.53e+6   1.53e+6
$
$     aopt

$
$       xp        yp        zp        a1        a2        a3

$
$       v1        v2        v3        d1        d2        d3
$
$$$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         0
$
$       t1        t2        t3        t4      nloc
     0.500     0.500     0.500     0.500
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         9                   4                             1
$
$       t1        t2        t3        t4      nloc
     0.015     0.015     0.015     0.015
$
$       b1        b2        b3        b4        b5        b6        b7        b8

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$    nid               x               y                z      tc      rc
*NODE
    3722 2.250000000E+00 2.500000000E+00 -1.25000000E+01
    3723 2.206770000E+00 2.938950000E+00 -1.25000000E+01
    3724 2.078730000E+00 3.361040000E+00 -1.25000000E+01
       .
       ...  in total, 3867 nodes defined
       .
    7586 1.200000000E+01 0.000000000E+00 -1.17000000E+01
    7587 -1.20000000E+01 0.000000000E+00 -1.30000000E+01
    7588 1.200000000E+01 0.000000000E+00 -1.30000000E+01
$
$$$$$  Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
```

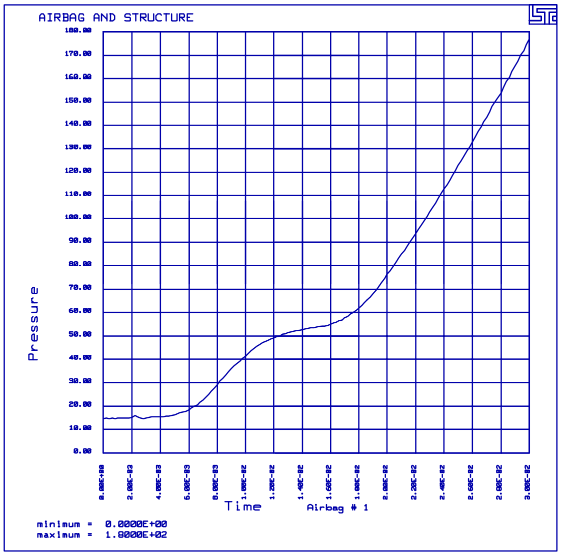
```
    6993       1    7547    7509    7148    7549
    6994       1    7509    7510    7149    7148
    6995       1    7510    7511    7150    7149
       .
       ...  in total, 3792 shells defined
       .
    6990       3    7078    7048    7144    7145
    6991       3    7108    7078    7145    7146
    6992       3    5998    7108    7146    7147
$
*END
```

Results:

taurus g=d3plot
19
state 15 rx 20 view



phs3
abstat
grid oset 0
180 pressure



LS-DYNA Manual Section: *BOUNDARY_PRESCRIBED_MOTION

Additional Sections:

*LOAD_SEGMENT

Example: Blow Molding

Filename: boundary_prescribed_motion.blow-mold.k

Description:

This problem includes two tools, a punch nose and a die tube. A blank tube is formed by blow molding the nose through the tube.

Model:

The hollow tube blank is made with 600 shell elements AND has an outer radius of 12.06 mm, an initial thickness of 1.37 mm, and an initial length of 53.5 mm. The internal pressure of the hollow tube blank is 40 N/mm^2 applied using the *LOAD_SEGMENT keyword. The tools are rigid shell elements. Only 1/4 of the system is modeled because of symmetry.

The motion of the punch nose and the end of the blank follow a linear motion with a total displacement of 15 mm (*BOUNDARY_PRESCRIBED_MOTION).

Reference:

Wei, Lixin

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
BLOWING MOLD
$
$  LSTC/KBS2 Example
$
$  Last Modified: October 21, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
  .150E-01         0      .000      .000      .000
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
      .000      .400         0
$
*CONTROL_BULK_VISCOSITY
$       Q2        Q1
     1.500      .060
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
      .100                             2
$   usrstr    usrfrc     nsbcs    interm     xpene     ssthk      ecdt   tiedprj
         0         0        10         0     4.000
$
*CONTROL_DAMPING
$   nrcyck     drtol    drfctr    drterm    tssfdr    irelal     edttl    idrflg
       250      .001      .995
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         1      .100
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3         0         0      .000         0       100
$
$
*DATABASE_BINARY_D3PLOT
$       dt       lcdt
  .200E-03
$
*DATABASE_BINARY_D3THDT
$       dt       lcdt
  .000E+00
$
```

```
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
         0         0         3         0         1         1         1         1
$   cmpflg    ieverp    beamip
         0         0         0         0         0         0
$
*DATABASE_GLSTAT
$       dt
  .100E-03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_SURFACE_TO_SURFACE_TITLE
$      cid      name
         3       IF1
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         2         3         3         0         0         0         0
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00         0 0.000E+00 1.000E+20
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
  .100E+01  .100E+01                      .098E+01  .098E+01  .100E+01  .100E+01
$
$
*CONTACT_SURFACE_TO_SURFACE_TITLE
$      cid      name
         4       IF4
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         3         3         3         0         0         0         0
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00         0 0.000E+00 1.000E+20
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
  .100E+01  .100E+01                      .095E+01  .095E+01  .100E+01  .100E+01
$
$
*CONTACT_SINGLE_SURFACE_TITLE
$      cid      name
         5       IF5
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         0         3         0         0         0         0         0
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00         0 0.000E+00 1.000E+20
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
  .100E+01  .100E+01                      .100E+01  .100E+01  .100E+01  .100E+01
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
```

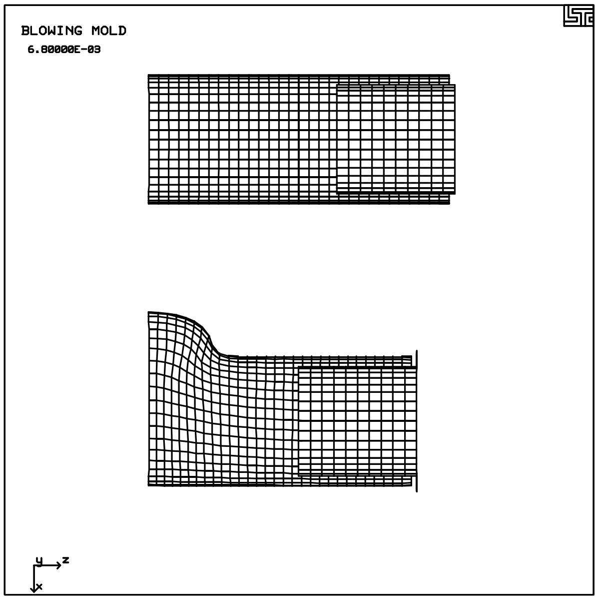
```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
die-1
         1         1         1
nose-2
         2         1         2
tube-3
         3         2         3
$

$$$$$  Materials
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         1 7.830E-09 2.070E+05 3.000E-01 0.000E+00 0.000E+00 0.000E+00
$      cmo      con1      con2
       1.0       7.0       7.0
$lco or a1        a2        a3        v1        v2        v3

$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2 7.830E-09 2.070E+05 3.000E-01 0.000E+00 0.000E+00 0.000E+00
$      cmo      con1      con2
       1.0       4.0       7.0
$lco or a1        a2        a3        v1        v2        v3

$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         3 8.900E-09 3.660E+03 3.000E-01 1.830E+01 0.000E+00 0.000E+00 0.000E+00
$        c         p      lcss      lcsr
  .000E+00  .000E+00  .000E+00  .000E+00
$  Plastic stress/strain curve
$     eps1      eps2      eps3      eps4      eps5      eps6      eps7      eps8
 0.000E+00 5.000E-03 5.000E-01 2.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$      es1       es2       es3       es4       es5       es6       es7       es8
 0.000E+00 1.830E+01 2.200E+02 4.650E+02 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2  .830E+00       2.0       1.0        .0
$       t1        t2        t3        t4      nloc
 2.000E+00 2.000E+00 2.000E+00 2.000E+00
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         2  .830E+00       2.0       1.0        .0
$       t1        t2        t3        t4      nloc
 1.370E+00 1.370E+00 1.370E+00 1.370E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

```
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      pid       dof       vad      lcid        sf       vid     death
         2         3         2         1     -15.0
$
*BOUNDARY_PRESCRIBED_MOTION_SET
$     nsid       dof       vad      lcid        sf       vid     death
         1         3         2         1     -15.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1         0
$          abscissa           ordinate
      .000000000E+00      .000000000E+00
      .165000000E-01      .110000000E+01
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8

      3061      3062      3093      3124      3155      3186      3217      3248
      3279      3310      3341      3372      3403      3434      3465      3496
      3527      3558      3589      3620      3651
$
*BOUNDARY_SPC_NODE
$      nid       cid      dofx      dofy      dofz     dofrx     dofry     dofrz
      3001         0         0         1         1         1         1         1
      3002         0         0         1         0         1         0         1
       .
       ...  in total, 81 SPC's defined
       .
      3650         0         0         1         0         1         0         1
      3651         0         0         1         0         1         0         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Loading Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_SEGMENT
$     lcid        sf        at        n1        n2        n3        n4
         1    40.000                3001      3002      3003      3004
         1    40.000                3002      3005      3006      3003
       .
       ...  in total, 600 pressure loads defined
       .
         1    40.000                3618      3619      3650      3649
         1    40.000                3619      3620      3651      3650
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
```

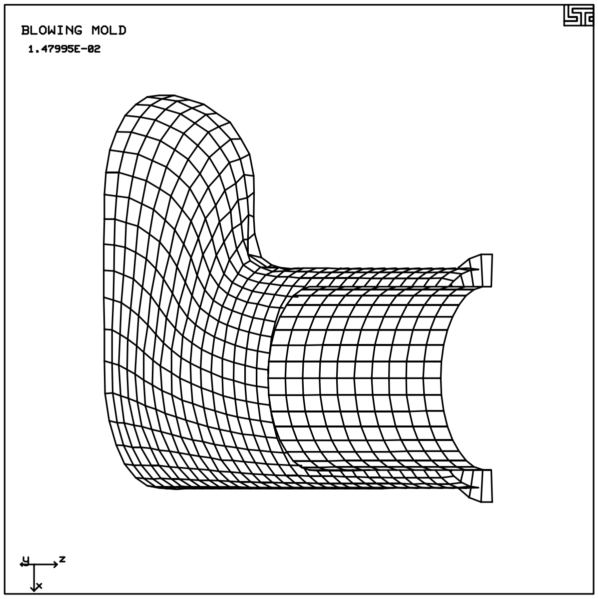
```
*NODE
$    nid                x                y                z       tc       rc
    1001  .130103000E+02 -.113825400E+01  .535000000E+02
    1002  .129937800E+02  .126376400E+01  .535000000E+02
       .
       ...  in total, 1437 nodes defined
       .
    3650 -.113750000E+02  .442958800E-05  .517166600E+02
    3651 -.113750000E+02  .442958800E-05  .534999900E+02
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
    1001       1    1001    1002    1003    1004
    1002       1    1004    1003    1005    1006
       .
       ...  in total, 1313 shells defined
       .
    2197       2    2226    2187    2198    2227
    2198       2    2227    2198    2209    2228
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rz -90 ry 90 -m 1 dist 6000
ytrans 40 view ytrans -50 s 35 over view
```



```
s 75
ry 30
center view
```



LS-DYNA Manual Section: *CONSTRAINED_GENERALIZED_WELD

Additional Sections:

*DATABASE_CROSS_SECTION_PLANE

Example: Two Plates Connected with Butt Welds

Filename: constrained.butt-weld.k

Description:

Two plates are connected by four butt welds. The plates are pulled apart and the center two welds fail.

Model:

Each plate is constructed with 12 shell elements. One end of one plate is fixed with SPC's. One end of the other plate has a prescribed motion condition defined. The other ends of the plates are butt welded together with failure criteria. Cross sections are defined through each plate to monitor the forces through the plates as they are pulled apart.

Results:

```
butt weld constraint failed between nodes      35 & 23
 :  Time      =   1.26913E+00 :  xl-force  =   5.56053E+00
 :  yl-force  =   2.28915E-03 :  zl-force  =  -1.93680E-07
 :  xl-moment =  -3.16675E-07 :  yl-moment =   9.09511E-07
 :  plastic ep=   0.00000E+00

 Stresses in weld:
 :  signn     =   2.78026E-01 :  tautn     =   0.00000E+00
 :  signm     =   9.09511E-08 :  tautm     =   0.00000E+00
 :  signs     =   0.00000E+00 :  tauts     =   1.14458E-04
 :  tautw     =  -9.68398E-09

 butt weld constraint failed between nodes     37 & 25
 :  Time      =   1.26913E+00 :  xl-force  =   5.56054E+00
 :  yl-force  =  -2.29328E-03 :  zl-force  =  -2.41027E-07
 :  xl-moment =   2.97763E-07 :  yl-moment =   3.22515E-07
 :  plastic ep=   0.00000E+00

 Stresses in weld:
 :  signn     =   2.78027E-01 :  tautn     =   0.00000E+00
 :  signm     =   3.22515E-08 :  tautm     =   0.00000E+00
 :  signs     =   0.00000E+00 :  tauts     =  -1.14664E-04
 :  tautw     =  -1.20514E-08
```

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Two plates connected with a Butt Weld
$
$  LSTC Example
$
$  Last Modified: October 16, 1997
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
      3.01
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                       1         6
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       0.2
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$
$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
       0.1
$
*DATABASE_MATSUM
$       dt
       0.1
$
*DATABASE_NODOUT
$       dt
```

```
       0.1
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4
        22        23        35        36
$
*DATABASE_SECFORC
$       dt
     0.010
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Cross Sections
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DATABASE_CROSS_SECTION_PLANE
$     psid       xct       yct       zct       xch       ych       zch
         0      15.0       0.0       0.0     100.0       0.0       0.0
$     xhev      yhev      xhev      lenl      lenm
      15.0       1.0       0.0
$
$
*DATABASE_CROSS_SECTION_PLANE
$     psid       xct       yct       zct       xch       ych       zch
         0      65.0       0.0       0.0     100.0       0.0       0.0
$     xhev      yhev      xhev      lenl      lenm
      65.0       1.0       0.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constrain the Plates Together with 4 Butt welds
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$  weld 1
$
*CONSTRAINED_GENERALIZED_WELD_BUTT
$     nsid       cid
        21
$
$    tfail      epsf      sigy      beta         L         D        Lt
                 0.3     0.250       0.9      10.0       2.0       1.0
$
*SET_NODE_LIST
$      sid
        21
$     nid1      nid2
        21        33
$
$
$$$$$$  weld 2
$
*CONSTRAINED_GENERALIZED_WELD_BUTT
$     nsid       cid
        23
$
$    tfail      epsf      sigy      beta         L         D        Lt
                 0.3     0.250       0.9      10.0       2.0       1.0
```

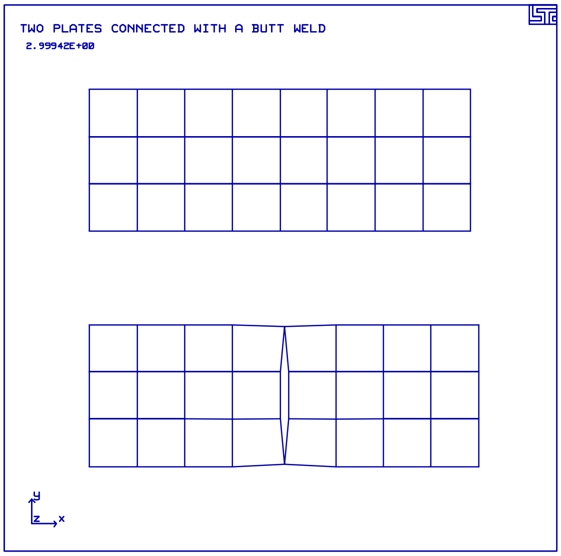
```
$
*SET_NODE_LIST
$      sid
        23
$     nid1      nid2
        23        35
$
$
$$$$$  weld 3
$
*CONSTRAINED_GENERALIZED_WELD_BUTT
$     nsid       cid
        25
$
$    tfail      epsf      sigy      beta         L         D        Lt

                 0.3     0.250       0.9      10.0       2.0       1.0
$
*SET_NODE_LIST
$      sid
        25
$     nid1      nid2
        25        37
$
$
$$$$$$  weld 4
$
*CONSTRAINED_GENERALIZED_WELD_BUTT
$     nsid       cid
        27
$
$    tfail      epsf      sigy      beta         L         D        Lt
                 0.3     0.250       0.9      10.0       2.0       1.0
$
*SET_NODE_LIST
$      sid
        27
$     nid1      nid2
        27        39
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$  Fix left end nodes
$
*BOUNDARY_SPC_NODE
$      nid       cid      dofx      dofy      dofz     dofrx     dofry     dofrz
        20         0         1         1         1         1         1         1
        22         0         1         1         1         1         1         1
        24         0         1         1         1         1         1         1
        26         0         1         1         1         1         1         1
$
$
$$$  Prescribe motion to right end nodes
$
*BOUNDARY_PRESCRIBED_MOTION_SET
$      nid       dof       vad      lcid        sf       vid
         1         1         0         1       1.0         0
```

```
$
*DEFINE_CURVE
$
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$           abscissa            ordinate
              0.0000                 0.0
              5.0000              2.0000
             20.0000              2.0000
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
        34        36        38        40
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
plate1
         2         2         1
plate2
         3         2         1
$
$
$$$$   Materials
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1   2.70e-6      68.9     0.330     0.286   0.00689
$
$      src       srp        fs
                           0.1
$
$
$$$$   Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         6
$
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$

*NODE
$    nid               x               y               z      tc      rc
```

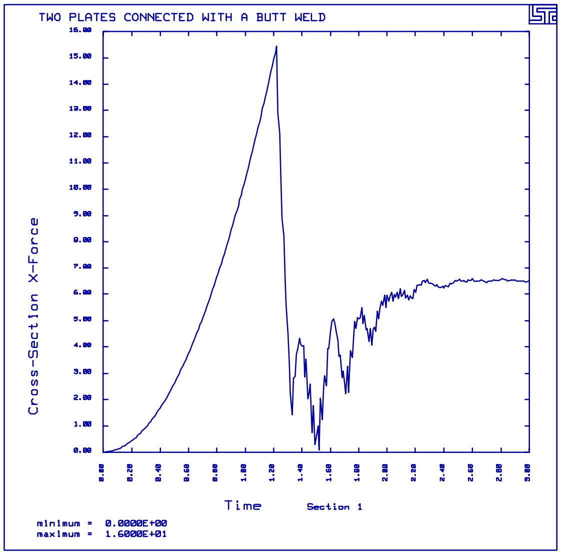
```
       1 5.000000000E+01 2.000000000E+01 0.000000000E+00
       2 6.000000000E+01 2.000000000E+01 0.000000000E+00
       .
       ...  in total, 40 nodes defined
       .
      39 4.000000000E+01 0.000000000E+00 0.000000000E+00
      40 8.000000000E+01 0.000000000E+00 0.000000000E+00
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       2      20      14       8      22
       2       2      14      15       9       8
       .
       ...  in total, 24 shells defined
       .
      23       3       5       6      32      31
      24       3       6      38      40      32
$
*END
```

Results:

```
taurus g=d3plot
ytran 25 view
ytran -50 state 16 over view
```



```
phs3
secforc
smooth 5
oset 0 16 x-for 1
```



LS-DYNA Manual Section: *CONSTRAINED_JOINT_PLANAR

Additional Sections:

*LOAD_NODE_POINT
*LOAD_SEGMENT
*INITIAL_VELOCITY_NODE
*CONSTRAINED_EXTRA_NODES_SET

Example: Sliding Blocks with Planar Joint

Filename: constrained.joint_planar.k

Description:

This problem illustrates a planar joint connecting two rigid bodies.

Model:

The first block measuring $2 \times 2 \times 2$ slides along a second block measuring $2 \times 2 \times 8$. A third flexible body controls the time step size. The first block has a ramped pressure of 100 psi applied to the top surface and ramped concentrated forces applied to a lower edge of 40 lbs. The initial velocity of the first block is 400 inches/second.

Input:

One joint definition consist of nodes 128, 126, 129 and 127 (*CONSTRAINED_JOINT_PLANAR). The nodes are extra nodes attached to the rigid bodies and are coincident (*CONSTRAINED_EXTRA_NODES_SET, *SET_NODE_LIST).

Results:

The plots show that the first block correctly slides across the second block.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
test planar joints
$
$  LSTC Example
$
$  Last Modified: August 29, 1997
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$  - part 1: fixed, long, rigid block
$  - part 2: rigid block which slides on top of part 1
$            initial velocity = 400
$  - part 3: elastic solid used to set time step
$
$
$   Units: lbf-s^2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Output
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     0.020
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
     0.001
$
*DATABASE_GLSTAT
$       dt
    0.0001
$
*DATABASE_JNTFORC
$       dt
    0.0001
$
*DATABASE_HISTORY_NODE
$   Define nodes that output into nodout
$      id1       id2       id3       id4       id5       id6       id7       id8
        91        21        94       128       126       129       127
$
*DATABASE_NODOUT
$       dt
    0.0001
$
*DATABASE_RBDOUT
$       dt
    0.0001
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Planar Joint
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONSTRAINED_JOINT_PLANAR
$
$       n1        n2        n3        n4        n5        n6       rps
       128       126       129       127                    0.000E+00
$
*CONSTRAINED_EXTRA_NODES_SET
$
$      pid      nsid
         1         1
$
*SET_NODE_LIST
$
$      sid
         1
$
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       126       127
$
*CONSTRAINED_EXTRA_NODES_SET
$
$      pid      nsid
         2         2
$
*SET_NODE_LIST
$
$      sid
         2
$
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       128       129
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
fixed rigid body
$
$      pid       sid       mid     eosid      hgid     igrav    adpopt
         1         1         1
$
*PART
sliding rigid body
         2         2         2
$
*PART
elastic body for time step control
         3         3         3
$
$
$$$$   Materials
$
*MAT_RIGID
$
$      mid        ro         e        pr         n    couple         m     alias
         1 7.850E-04 3.000E+07 3.000E-01
```

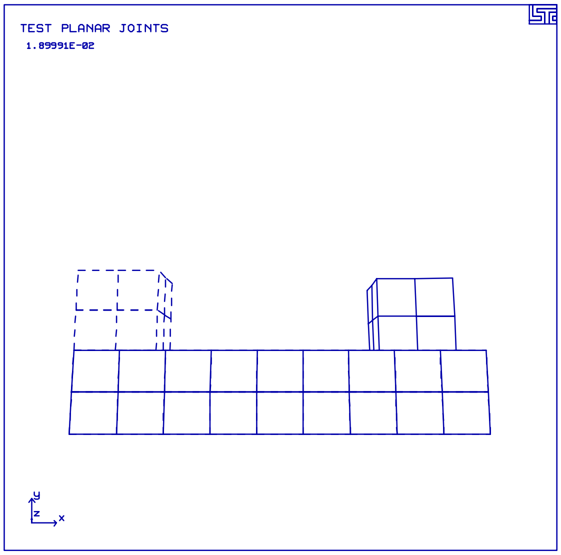
```
$
$      cmo      con1      con2
 1.000E+00 7.000E+00 7.000E+00
$
$   lco/a1        a2        a3        v1        v2        v3

$
*MAT_RIGID
$
$      mid        ro         e        pr         n    couple         m     alias
         2 7.850E-04 3.000E+07 3.000E-01
$
$      cmo      con1      con2
$

$   lco/a1        a2        a3        v1        v2        v3

$
*MAT_ELASTIC
$
$      mid        ro         e        pr
         3 7.850E-04 3.000E+07 3.000E-01
$
$
$$$$    Sections
$
*SECTION_SOLID
$      sid    elform
         1         0
         2         0
         3         0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Pressure load on top of block
$
*LOAD_SEGMENT
$
$     lcid        sf        at        n1        n2        n3        n4
         1 1.000E+00 0.000E+00        97       106       107        98
         1 1.000E+00 0.000E+00       106       115       116       107
         1 1.000E+00 0.000E+00        98       107       108        99
         1 1.000E+00 0.000E+00       107       116       117       108
$
*DEFINE_CURVE
$
$     lcid      sidr      scla      sclo      offa      offo
         1         0 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$           abscissa            ordinate
      0.00000000E+00      0.00000000E+00
      9.99999978E-03      1.00000000E+02
      1.99999996E-02      1.00000000E+02
$
$
$$$$  Force load on lower edge of block
$
*LOAD_NODE_POINT
$
```

```
$      nid       dof      lcid        sf       cid        m1        m2        m3
        91         3         2-1.000E+00         0
        92         3         2-1.000E+00         0
        93         3         2-1.000E+00         0
$
*DEFINE_CURVE
$
$     lcid      sidr      scla      sclo      offa      offo
         2         0 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$           abscissa            ordinate
      0.00000000E+00      0.00000000E+00
      1.99999996E-02      4.00000000E+01
$$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*INITIAL_VELOCITY_NODE
$
$      nid        vx        vy        vz       vxe       vye       vze
$
$$$  Nodes on sliding block
$
        91 4.000E+02 0.000E+00 0.000E+00
        92 4.000E+02 0.000E+00 0.000E+00
        93 4.000E+02 0.000E+00 0.000E+00
        94 4.000E+02 0.000E+00 0.000E+00
        95 4.000E+02 0.000E+00 0.000E+00
        96 4.000E+02 0.000E+00 0.000E+00
        97 4.000E+02 0.000E+00 0.000E+00
        98 4.000E+02 0.000E+00 0.000E+00
        99 4.000E+02 0.000E+00 0.000E+00
       100 4.000E+02 0.000E+00 0.000E+00
       101 4.000E+02 0.000E+00 0.000E+00
       102 4.000E+02 0.000E+00 0.000E+00
       103 4.000E+02 0.000E+00 0.000E+00
       104 4.000E+02 0.000E+00 0.000E+00
       105 4.000E+02 0.000E+00 0.000E+00
       106 4.000E+02 0.000E+00 0.000E+00
       107 4.000E+02 0.000E+00 0.000E+00
       108 4.000E+02 0.000E+00 0.000E+00
       109 4.000E+02 0.000E+00 0.000E+00
       110 4.000E+02 0.000E+00 0.000E+00
       111 4.000E+02 0.000E+00 0.000E+00
       112 4.000E+02 0.000E+00 0.000E+00
       113 4.000E+02 0.000E+00 0.000E+00
       114 4.000E+02 0.000E+00 0.000E+00
       115 4.000E+02 0.000E+00 0.000E+00
       116 4.000E+02 0.000E+00 0.000E+00
       117 4.000E+02 0.000E+00 0.000E+00
$
$$$  Extra nodes on sliding rigid block
$
       128 4.000E+02 0.000E+00 0.000E+00

       129 4.000E+02 0.000E+00 0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

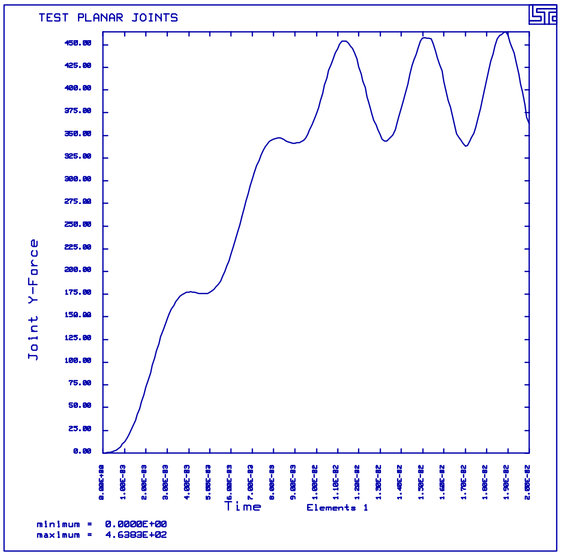
```
$$$$  Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1 0.000000000E+00 0.000000000E+00 0.000000000E+00       0       0
       2 1.111111164E+00 0.000000000E+00 0.000000000E+00       0       0
       3 2.222222328E+00 0.000000000E+00 0.000000000E+00       0       0
       .
       ...  in total, 129 nodes defined
       .
     127 1.000000000E+01 4.000000000E+00 1.000000000E+00       0       0
     128 1.000000000E+01 0.000000000E+00 1.000000000E+00       0       0
     129 1.000000000E+01 4.000000000E+00 1.000000000E+00       0       0
$
*ELEMENT_SOLID
$
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       1       2      12      11      31      32      42      41
       2       1       2       3      13      12      32      33      43      42
       3       1       3       4      14      13      33      34      44      43
       .
       ...  in total, 45 solids defined
       .
      43       2     103     104     107     106     112     113     116     115
      44       2     104     105     108     107     113     114     117     116
      45       3     118     119     121     120     122     123     125     124
$
*END
```

Results:

```
taurus g=d3plot
19
<m 3 rx -10 udg 1 state 20 over view
```



```
phs3
jntforc
oscl -1 y-force
```



LS-DYNA Manual Section: *CONSTRAINED_JOINT_REVOLUTE

Additional Sections:

*CONSTRAINED_JOINT_STIFFNESS
*CONTROL_TIMESTEP

Example: Hinged Shell with Stop Angle (Revolute Joint)

Filename: constrained.joint_revolute.k

Description:

Two rigid shell elements are joined together using a revolute joint. A stop angle is defined so that the rotating plate can only rotate 30 degrees relative to the other plate.

Model:

A pair of concentrated loads are applied to the end nodes of a hinge-jointed shell system using *LOAD_NODE_POINT. One of the rigid plates is fixed by using the capability within the *MAT_RIGID keyword. The rotating plate has a stop angle of 30 degrees relative to the fixed plate defined using the *CONSTRAINED_JOINT_STIFFNESS_GENERLAIZED keyword.

Because all components in the model are rigid, the time step needs to be controlled by limiting the maximum time step to 4.15E-06 s. (In deformable structures, the minimum time step is usually the one of concern.)

Results:

The rotating plate at several states are shown imposed on each other. The maximum rotated angle is closer to 38 degrees rather than the specified 30 degrees. This is because the joint stiffness actual defines the angle at which the resistance force is to begin. The forces associated with stopping the rotating plate can be determined by examining the jntforc ascii file.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
hinged shell w/ stop angle
$
$  LSTC Example
$
$  Last Modified: October 16, 1997
$
$ - This problem has a pair of concentrated loads applied to
$   the end nodes of a hinge-jointed shell system.
$
$ - 30 degree stop angle (must add joint stiffness, local coord system)
$
$ - control timestep with maximum 4.15E-06
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
 2.000E-02
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                                                           5
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         5
$           abscissa            ordinate
                 0.0            4.15E-06
                 1.0            4.15E-06
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 5.000E-04
$
*DATABASE_GLSTAT
$       dt
    0.0001
$
*DATABASE_JNTFORC
$       dt
 1.000E-04
$
*DATABASE_NODOUT
$       dt
    0.0001
$
*DATABASE_HISTORY_NODE
$     nid1      nid2
         3         4
$
```

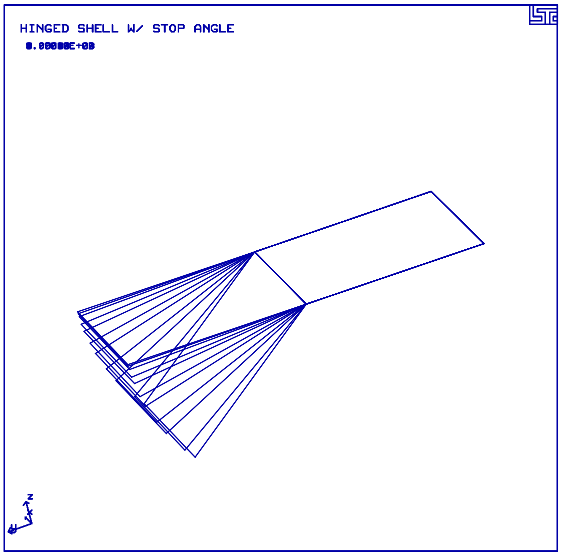
```
*DATABASE_RBDOUT
$       dt
    0.0001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Revolute Joint
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONSTRAINED_JOINT_REVOLUTE
$
$  Create a revolute joint between two rigid bodies.  The rigid bodies must
$  share a common edge to define the joint along.  This edge, however, must
$  not have the nodes merged together.  Rigid bodies A and B will rotate
$  relative to each other along the axis defined by the common edge.
$
$  Nodes 1 and 2 are on rigid body A and coincide with nodes 9 and 10
$  on rigid body B, respectively.  (This defines the axis of rotation.)
$
$  The relative penalty stiffness on the revolute joint is to be 1.0,
$  the joint is well lubricated, thus no damping at the joint is supplied.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$       n1        n2        n3        n4        n5        n6       rps      damp
         1         9         2        10                             1.0
$
$
$$$$$$$$$$$$  Define a joint stiffness for the revolute joint described above.
$
$  Attributes of the joint stiffness:
$    - Used for defining a stop angle of 30 degrees rotation
$        (i.e., the joint allows a positive rotation of 30 degrees and
$           then imparts an elastic stiffness to prevent futher rotation)
$    - Define between rigid body A (part 1) and rigid body B (part 2)
$    - Define a local coordinate system along the revolute axis
$        on rigid body A - nodes 1, 2 and 3 (cid = 5).  This is used to
$        define the revolute angles phi (PH), theta (T), and psi (PS).
$    - The elastic stiffness per unit radian for the stop angles
$        are 100, 10, 10 for PH, T, and PS, respectively.
$    - Values not specified are not used during the simulation.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONSTRAINED_JOINT_STIFFNESS_GENERALIZED
$     jsid      pidA      pidB      cidA      cidB
         1         1         2         5         5
$
$   lcidPH     lcidT    lcidPS   dlcidPH    dlcidT   dlcidPS

$
$     esPH      fmPS       esT       fmT      esPS      fmPS
     100.0                10.0                10.0
$
$    nsaPH     psaPH      nsaT      psaT     nsaPS     psaPS
               30.0
$
$
*DEFINE_COORDINATE_NODES
$      cid        n1        n2        n3
```

```
         5         1         2         3
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
         3         3         1-1.000E+00
         4         3         1-1.000E+00
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
      0.00000000E+00      1.00000000E+00
      1.00000000E+00      1.00000000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
rotating
         1         1         1         0
fixed
         2         1         2         0
$
$$$$  Materials
$
*MAT_RIGID
$
$      mid        ro         e        pr         n    couple         m     alias
         1 7.000E-04 3.000E+07 3.000E-01
$
$      cmo      con1      con2

$
$   lco/a1        a2        a3        v1        v2        v3

$
*MAT_RIGID
$
$      mid        ro         e        pr         n    couple         m     alias
         2 7.000E-04 3.000E+07 3.000E-01
$
$      cmo      con1      con2
       1.0         7         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
$$$$  Sections
$
```

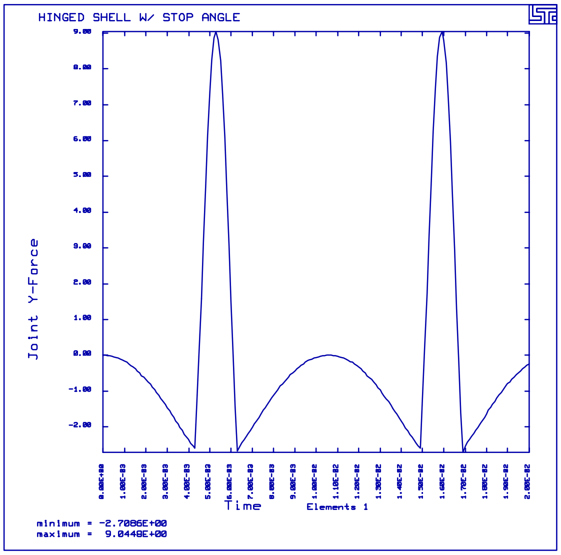
```
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2                    3.0
$       t1        t2        t3        t4      nloc
       0.1       0.1       0.1       0.1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
       1 0.000000000E+00 0.000000000E+00 0.000000000E+00       0       0
       2 1.000000000E+00 0.000000000E+00 0.000000000E+00       0       0
       3 0.000000000E+00 1.000000000E+00 0.000000000E+00       0       0
       4 1.000000000E+00 1.000000000E+00 0.000000000E+00       0       0
       7 0.000000000E+00-1.000000000E+00 0.000000000E+00       0       0
       8 1.000000000E+00-1.000000000E+00 0.000000000E+00       0       0
       9 0.000000000E+00 0.000000000E+00 0.000000000E+00       0       0

      10 1.000000000E+00 0.000000000E+00 0.000000000E+00       0       0
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       3       4       2
       3       2       7       9      10       8
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rz 90 rx -45 ry 30 rx -15 rz 30 ry -20 s 1 v s 3 over v
s 5 over v ...repeat for all odd states up to ... s 21 over v
```



```
phs3
jntforc
y-force
```



LS-DYNA Manual Section: *CONSTRAINED_LINEAR

Additional Sections:

BOUNDARY_PRESCRIBED_MOTION_NODE
DEFINE_CURVE

Example: Linearly Constrained Plate

Filename: constrained.linear.plate.k

Description:

The center node of a plate moves in the normal direction. Two other nodes that are neighbors to the center node are constrained such that their displacement in the normal direction is identical.

Model:

The plate is made of an elastic material measuring 40 × 40 × 2 mm^3 and contains 64 Hughes-Liu shell elements. The center node displacement increases linearly. At the termination time, 0.0005 seconds, the displacement is 15 mm. The degree of freedom in the z-direction for the two nodes is identical.

Input:

A load curve defines the magnitude of the prescribed displacement of the center node (*BOUNDARY_PRESCRIBED_MOTION_NODE, *DEFINE_CURVE). A linear constraint card defines the coupling of the displacement in the z-direction between the two nodes (*CONSTRAINED_LINEAR). Two equal coefficients with opposite signs control the displacement.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

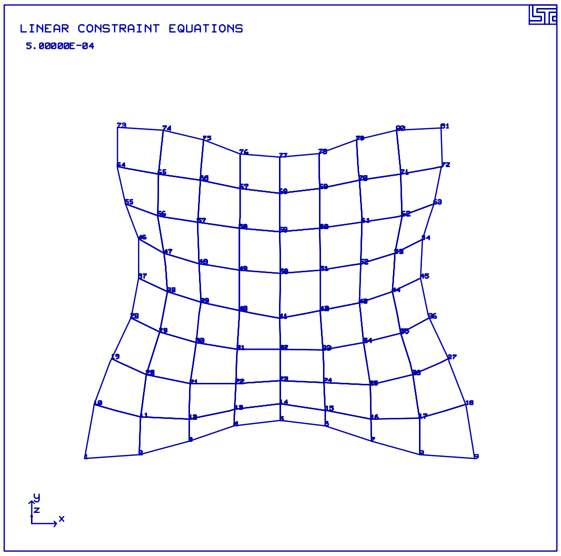
```
*KEYWORD
*TITLE
Linear Constraint Equations
$
$  LSTC Example
$
$  Last Modified: September 3, 1997
$
$   Units: mm, s
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
    0.0005
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
       0.1                   2
$
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                                 1
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
   0.00002
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
   0.00001
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$
$   cmpflg    ieverp    beamip

$
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
        40        41        42
$
*DATABASE_NODOUT
```

```
$       dt
   0.00001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constraints and Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  nodes 40 and 42 are constrained to have identical z-direction motion
$
*CONSTRAINED_LINEAR
$      num
         2
$
$      nid      dofx      dofy      dofz     dofrx     dofry     dofrz      coef
        40                             1                                  1.00
        42                             1                                 -1.00
$
$
$$$$  node 41 is displaced in the z-direction according to load curve 1
$
*BOUNDARY_PRESCRIBED_MOTION_NODE
$      nid       dof       vad      lcid        sf       vid
        41         3         2         1       1.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$           abscissa           ordinate
                 0.0                0.0
              0.0005              -15.0
              0.0015              -15.1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*PART
Impacted Material
$      pid       sid       mid     eosid      hgid    adpopt
         1         1         1         0         0         0
$
$
$$$$$$  Materials
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1   2.00e-8  100000.0     0.300
$
$
$$$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         6   0.83333       2.0       3.0
$
$       t1        t2        t3        t4      nloc
```

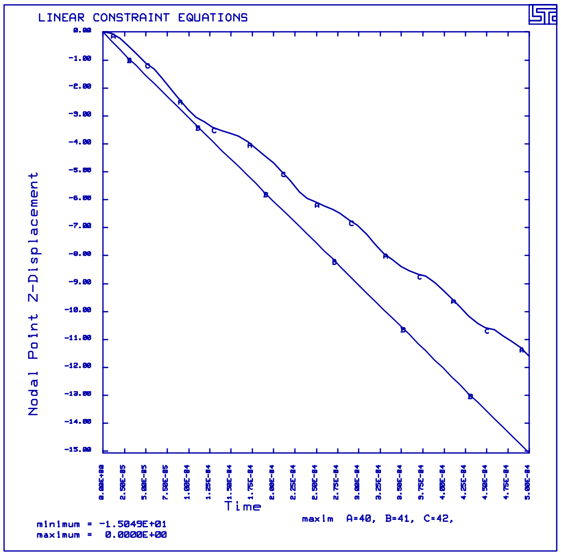
```
       2.0       2.0       2.0       2.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  z-translational constraints are placed on several nodes
$
*NODE
$    nid               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       3       0
       2    5.000000E+00    0.000000E+00    0.000000E+00       3       0
       3    1.000000E+01    0.000000E+00    0.000000E+00       3       0
       .
       ...  in total, 81 nodes defined
       .
      79    3.000000E+01    4.000000E+01    0.000000E+00       3       0
      80    3.500000E+01    4.000000E+01    0.000000E+00       3       0
      81    4.000000E+01    4.000000E+01    0.000000E+00       3       0
$
$$$$$  Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2      11      10
       2       1       2       3      12      11
       3       1       3       4      13      12
       .
       ...  in total, 64 shells defined
       .
      62       1      69      70      79      78
      63       1      70      71      80      79
      64       1      71      72      81      80
$
*END
```

Results:

```
taurus g=d3plot
19
time 5e-4 rx -20 ndplt
```



```
phs3
nodout
z-disp
```



LS-DYNA Manual Section: *CONSTRAINED_SHELL_TO_SOLID

Additional Sections:

*LOAD_SEGMENT

Example: Impulsively Loaded Cap with Shells and Solids

Filename: constrained.shell_solid.dome.k

Description:

A dome has an impulsive pressure load. The dome contains shell and brick element joined with shell-brick interfaces.

Model:

Only 1/4 of the dome is modeled due to symmetry. The dome shells are Hughes-Liu shell elements with three integration point through the thickness. Four shell elements have a pressure load of 5,308 psi over 0.0017246 square inches. The termination time is 0.0004 seconds.

Input:

The model contains one shell-brick goup that has 7 shell nodes tied to 5 brick node (*CONSTRAINED_SHELL_TO_SOLID). The model contains four pressure surfaces (*LOAD_SEGMENT). Five nodes are written to the time history ASCII database file nodout (*DATABASE_HISTORY_NODE, *DATABASE_NODOUT).

Results:

The plots show the response of the dome.

Reference:

T. Littlewood

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Impulsively Loaded Cap with Shell-Brick Interfaces
$
$  LSTC Example
$
$  Last Modified: September 4, 1997
$
$   Units: lbf-s^2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
    0.0004
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
   0.00001
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 5.000E-07
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$
$   cmpflg    ieverp    beamip

$
*DATABASE_ELOUT
$       dt
 5.000E-07
$
*DATABASE_HISTORY_SHELL
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
*DATABASE_HISTORY_SOLID
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
*DATABASE_GLSTAT
$       dt
 5.000E-07
$
*DATABASE_NODOUT
$       dt
 5.000E-07
```

```
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
         1       116       284       361       326
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constraints
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Constrain shell nodes on the inner radius of the dome shells
$$$$  to the outer radius of the dome solids
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       326         1
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       116       158       200       242       284
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       327         2
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         2
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       117       159       201       243       285
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       328         3
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         3
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       118       160       202       244       286
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       329         4
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         4
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       119       161       203       245       287
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       330         5
```

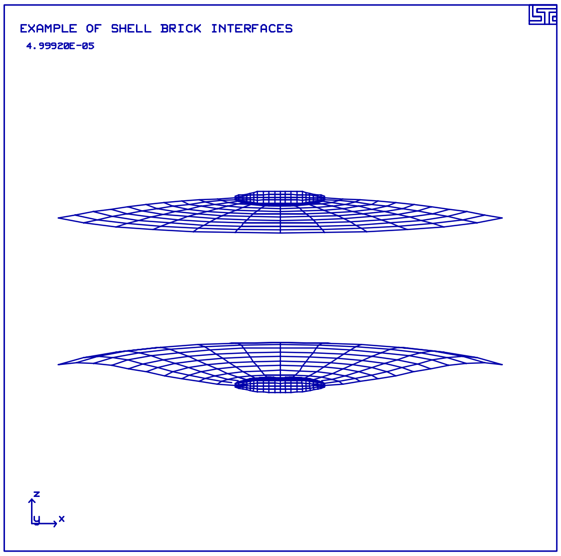
```
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         5
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       120       162       204       246       288
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       331         6
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         6
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       121       163       205       247       289
$
$
*CONSTRAINED_SHELL_TO_SOLID
$      nid      nsid
       332         7
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         7
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       122       164       206       248       290
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Loads
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Load 4 segments with pressure at 5,308 psi for 2.0E-04 seconds
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_SEGMENT
$     lcid        sf        at        n1        n2        n3        n4
         1 1.000E+00 0.000E+00         1         2         4         3
         1 1.000E+00 0.000E+00         2         5         7         4
         1 1.000E+00 0.000E+00         3         4         8         6
         1 1.000E+00 0.000E+00         4         7         9         8
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$                    a                   o
           0.000E+00           5.308E+04
           2.000E-04           5.308E+04
           2.010E-04           0.000E+00
           1.000E+00           0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
```

```
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Brick
         1         1         1         0         0         0
Brick2
         2         1         1         0         0         0
Shell
         3         2         1         0         0         0
$
$
$$$$$$  Materials
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         1   2.00e-4  29.00e+6     0.330
$
$
$$$$$$  Sections
$
*SECTION_SOLID
$      sid    elform
         1         0
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2
$
$       t1        t2        t3        t4      nloc
 1.576E-02 1.576E-02 1.576E-02 1.576E-02
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Many nodal constraints applied in the *NODE cards - this is because
$$$$  the model has symmetry and only 1/4 of it is actually modeled.
$
$    nid               x               y               z      tc      rc
*NODE
       1    0.000000E+00    0.000000E+00    4.791520E+00       4       7
       2    2.267646E-02    0.000000E+00    4.791466E+00       2       6
       3    0.000000E+00    2.267646E-02    4.791466E+00       1       5
       .
       ...  in total, 402 nodes defined
       .
     400    4.550468E-01    7.784918E-01    4.681861E+00       7       7
     401    2.396768E-01    8.693790E-01    4.681861E+00       7       7
     402    0.000000E+00    9.015844E-01    4.681861E+00       7       7
$
$$$$$  Elements - Solids
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       1       3       4       2      24      26      27      25

       2       1       3       6       8       4      26      29      31      27
       3       1       6      13      12       8      29      36      35      31
       .
       ...  in total, 204 solids defined
```

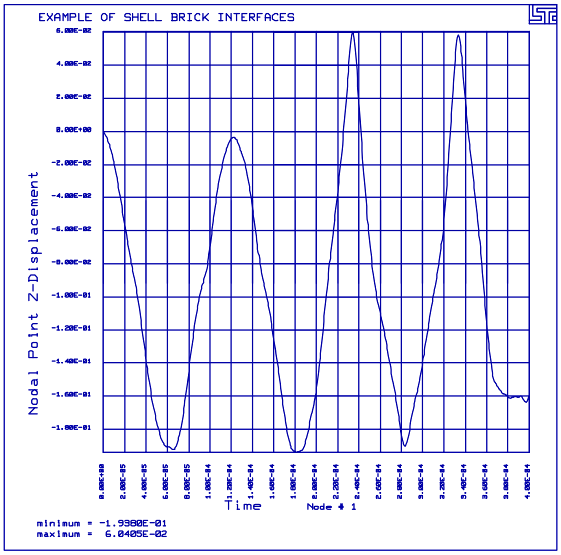
```
       .
     202       2     280     281      44      43     322     323      21      20
     203       2     281     282      45      44     323     324      22      21
     204       2     282     283      46      45     324     325      23      22
$
$$$$$  Elements - Shells
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       3     326     333     334     327
       2       3     327     334     335     328
       3       3     328     335     336     329
       .
       ...  in total, 60 shells defined
       .
      58       3     392     399     400     393
      59       3     393     400     401     394
      60       3     394     401     402     395
$
*END
```

Results:

```
taurus g=d3plot
19
rayz rx -90 center ytran .3 v ytran -.6 s 6 over v
```



```
phs3
nodout
grid z-disp
1
```



LS-DYNA Manual Section: *CONSTRAINED_SPOTWELD

Additional Sections:

*BOUNDARY_PRESCRIBED_MOTION_SET
*DATABASE_CROSS_SECTION_PLANE
*DATABASE_CROSS_SECTION_SET

Example: Spot Weld Secures Two Plates

Filename: constrained.spotweld.plates.k

Description:

Two overlapping plates are connected using three spotwelds. The plates are pulled apart until the spot welds reach the defined failure condition.

Model:

The two plates measure 80 × 40 × 1 mm^3 and are defined with S/R Hughes-Liu shell elements to control hourglassing. The location of the spotwelds connecting the two plates is in the center of the overlapping section. One end of the plate has fixed constraints and the other end of the other plate has linearly increasing displacement.

Input:

The nodal point cards contain the boundary conditions at one end of the plate (*NODES). *BOUNDARY_PRESCRIBED_MOTION_SET defines the nodal motion of the end of the other plate. Massless beams simulate the connection between the plates at three locations (*CONSTRAINED_SPOTWELD). The definitions include failure as a function of the axial and shear force.

The ASCII file swforc contains the axial and shear forces on the spotweld (*DATABASE_SWFORC). A cross section is defined through each of the plates using two different techniques (*DATABASE_CROSS_SECTION_PLANE, *DATABASE_CROSS_SECTION_SET). Forces and moments through the cross sections are stored in the ASCII file secforc (*DATABASE_SECFORC).

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Two Spotwelded Plates Pulled Apart with a Specified Velocity
$
$  LSTC Example
$
$  Last Modified: September 4, 1997
$
$  Model initially changed from old lstc example to partially reflect paper
$  by Matzenmiller, et al (ls-dyna conf 9/94) -  Major differences include the
$  material and element formulation, units, and velocity loading.
$
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
      8.00
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                       1
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       0.2
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
     99999
$
*DATABASE_GLSTAT
$       dt
     0.010
$
*DATABASE_MATSUM
$       dt
     0.010
$
*DATABASE_NODFOR
$       dt
     0.010
$
*DATABASE_NODAL_FORCE_GROUP
$     nsid       cid
```

```
       201
$
*SET_NODE_LIST
$      sid
       201
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       213       123
$
*DATABASE_NODOUT
$       dt
     0.010
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
       123       233
$
*DATABASE_SECFORC
$       dt
     0.010
$
*DATABASE_SWFORC
$       dt
     0.010
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constrain the Plates Together
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$  Three spotwelds across the plate, with failure defined.
$
*CONSTRAINED_SPOTWELD
$       n1        n2        sn        sf         n         m
       212       122     7.854     4.534       2.0       2.0
       213       123     7.854     4.534       2.0       2.0
       214       124     7.854     4.534       2.0       2.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Motion Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$  Prescribe the velocity of the nodes on one end of the plate.
$
*BOUNDARY_PRESCRIBED_MOTION_SET
$      nid       dof       vad      lcid        sf       vid
         1         1         0         1       1.0         0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
              0.0000                 0.0
             10.0000              0.3048
             20.0000              0.3048
$
*SET_NODE_LIST
$      sid
         1
```

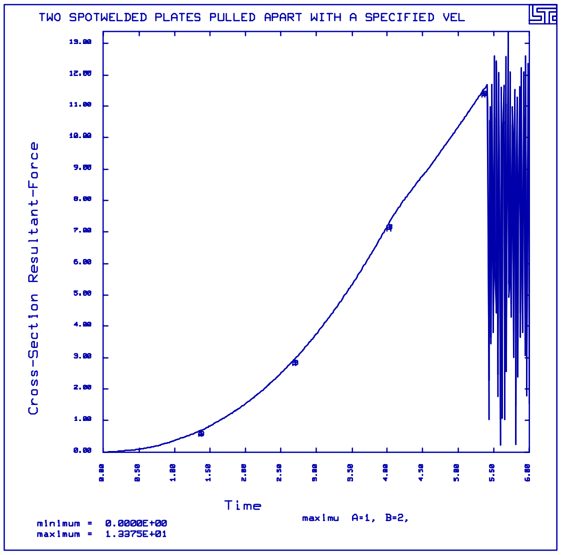
```
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       231       232       233       234       235
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
plate_1
         1         1         1
plate_2
         2         1         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1   2.70e-6      68.9     0.330     0.286   0.00689
$      src       srp        fs

$
$$$$  Element formulation 6 (S/R Hughes-Liu) is used to prevent hourglassing.
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         6                   3
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Cross Sections
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$  Two cross sections defined - one through each plate.  Two different
$    methods for defining the cross sections are used.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$  cross section through plate 1
$
```

```
*DATABASE_CROSS_SECTION_PLANE
$     psid       xct       yct       zct       xch       ych       zch
         0      30.0       0.0       0.0      31.0       0.0       0.0
$     xhev      yhev      xhev      lenl      lenm
      30.0       1.0       0.0
$
$$$  cross section through plate 2
$
*DATABASE_CROSS_SECTION_SET
$     nsid      hsid      bsid      ssid      tsid      dsid
         4                             2
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         4
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       226       227       228       229       230
$
*SET_SHELL_LIST
$      sid       da1       da2       da3       da4
         2
$     eid1      eid2      eid3      eid4      eid5      eid6      eid7      eid8

       221       222       223       224
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
     101    0.000000E+00    0.000000E+00    0.000000E+00       7       0
     102    0.000000E+00    1.000000E+01    0.000000E+00       7       0
     103    0.000000E+00    2.000000E+01    0.000000E+00       7       0
       .
       ...  in total, 70 nodes defined
       .
     233    1.200000E+02    2.000000E+01    2.000000E+00       5       0
     234    1.200000E+02    3.000000E+01    2.000000E+00       5       0
     235    1.200000E+02    4.000000E+01    2.000000E+00       5       0
$
$$$$$$$$  SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
     101       1     107     102     101     106
     102       1     108     103     102     107
     103       1     109     104     103     108
       .
       ...  in total, 48 shells defined
     222       2     233     228     227     232
     223       2     234     229     228     233
     224       2     235     230     229     234
$
*END
```

Results:

```
taurus g=d3plot
19
rx -80 state 28 view
```

```
phs3
secforc
aset 0 6 r-forc
```



LS-DYNA Manual Section: *CONTACT

Additional Sections:

*INITIAL_VELOCITY

Example: Shell Rebounds from Plate Using Five Contact Types

Filename: contact.plates.k

Description:

A shell element drops and rebounds on an elastic plate.

Model:

The plate measures 40 × 40 × 1 mm^3 and contains 16 shell elements. The dropped shell element has a side length of 10 mm, a thickness of 2 mm and drop height of 10 mm. All shell elements are elastic with Belytschko-Tsay formulation. The dropped shell element has an initial velocity of 100,000 mm/second vertically towards the plate. The calculations terminate at 0.0002 seconds.

Input:

All four nodes of the dropped shell element have an initial velocity specified by *INITIAL_VELOCITY. Contact types 3, 5 and 10 use the dropped shell element as slave side and the four shell elements in the center of the plate as master side. The example file has type 3 contact activated, while the other contact types are commented out. To change contact types, simply comment out type 3 and un-comment the desired contact.

Type 3 contact is a two way surface to surface algorithm. The segments on the slave side are checked for penetration of the master segment then the opposite search takes place.

Type 4 is a single surface algorithm. The nodes of all segments are checked for penetration of all segments.

Type 5 is a node to surface one way algorithm. The program checks that no slave node penetrates any master segment.

Type 10 converts surface to surface definition into a node to surface definition.

Type 13 is a more robust version of the single surface algorithm.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Sliding Interface Types 3,4,5,10,13
$
$  LSTC Example
$
$  Last Modified: September 5, 1997
$
$  Five different contacts are defined for the same problem.  The only one
$  active is type 3, surface to surface.  The other four are commented out.
$  To switch contact types, comment out the active one and remove the comments
$  from the desired one.
$
$  Units: mm, s
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
   .200E-3
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         1         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                0.50         0
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 0.0100E-3
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 2.0000E-3
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$   cmpflg    ieverp    beamip

$
*DATABASE_GLSTAT
$       dt
  0.01e-04
$
*DATABASE_NCFORC
$       dt
  0.01e-04
$
*DATABASE_NODOUT
```

```
$       dt
  0.01e-04
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
        12        13       101
$
*DATABASE_MATSUM
$       dt
  0.10e-05
$
*DATABASE_RCFORC
$       dt
  0.01e-04
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 3, surface to surface
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2                                                 1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*SET_SEGMENT
$      sid
         1
$       n1        n2        n3        n4
       101       103       104       102
$
*SET_SEGMENT
$      sid
         2
$       n1        n2        n3        n4
         7         8        13        12
         8         9        14        13
        12        13        18        17
        13        14        19        18
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 4, single surface
$                      to make active, remove the $$ from the lines below
$
$$*CONTACT_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
$$         1         0                                                 1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt
$$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
$$
$
$$*SET_SEGMENT
$      sid
```

```
$$         1
$       n1        n2        n3        n4
$$       101       103       104       102
$$         7         8        13        12
$$         8         9        14        13
$$        12        13        18        17
$$        13        14        19        18
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 5, node to surface
$                     to make active, remove the $$ from the lines below
$
$$*CONTACT_NODES_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
$$         1         2         4                                       1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt
$$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
$$
$
$$*SET_NODE_LIST
$      sid
$$         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
$$       101       103       104       102
$
$$*SET_SEGMENT
$      sid
$$         2
$       n1        n2        n3        n4
$$         7         8        13        12
$$         8         9        14        13
$$        12        13        18        17
$$        13        14        19        18
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 10, surface to surface
$                     to make active, remove the $$ from the lines below
$
$$*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
$$         1         2                                                 1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt
$$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
$$
$
$$*SET_SEGMENT
$      sid
$$         1
$       n1        n2        n3        n4
$$       101       103       104       102
$
$$*SET_SEGMENT
$      sid       da1       da2       da3       da4
$$         2
$       n1        n2        n3        n4
$$         7         8        13        12
$$         8         9        14        13
$$        12        13        18        17
$$        13        14        19        18
```

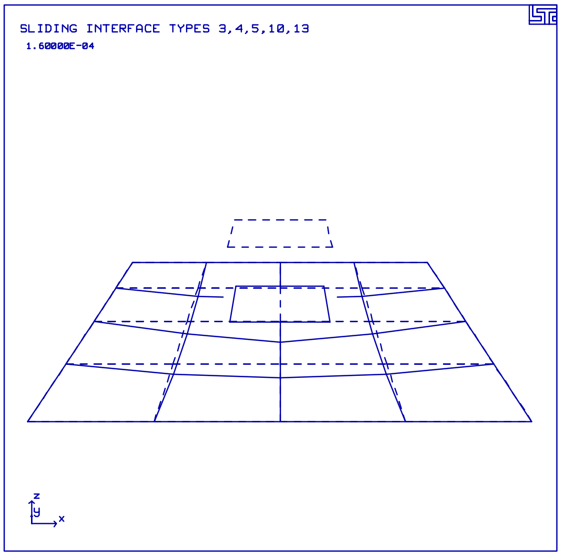
```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 13, automatic single surface
$                     to make active, remove the $$ from the lines below
$
$$*CONTACT_AUTOMATIC_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
$$         0         0                                                 1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt
$$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
$$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes of the Impactor Material are given an initial velocity.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
         1
$       vx        vy        vz
       0.0       0.0 -100000.0
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       101       102       103       104
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Impacted Material
         1         1         1
Impactor Material
         2         2         1
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1   1.00e-8  100000.0     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333       2.0       3.0
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
```

```
         2             0.83333       2.0       3.0
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$ Outer edge nodes of the Impacted Material are fixed in translation (tc = 7)
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       0
       2    1.000000E+01    0.000000E+00    0.000000E+00       7       0
       3    2.000000E+01    0.000000E+00    0.000000E+00       7       0
       4    3.000000E+01    0.000000E+00    0.000000E+00       7       0
       5    4.000000E+01    0.000000E+00    0.000000E+00       7       0
       6    0.000000E+00    1.000000E+01    0.000000E+00       7       0
       7    1.000000E+01    1.000000E+01    0.000000E+00       0       0
       8    2.000000E+01    1.000000E+01    0.000000E+00       0       0
       9    3.000000E+01    1.000000E+01    0.000000E+00       0       0
      10    4.000000E+01    1.000000E+01    0.000000E+00       7       0
      11    0.000000E+00    2.000000E+01    0.000000E+00       7       0
      12    1.000000E+01    2.000000E+01    0.000000E+00       0       0
      13    2.000000E+01    2.000000E+01    0.000000E+00       0       0
      14    3.000000E+01    2.000000E+01    0.000000E+00       0       0
      15    4.000000E+01    2.000000E+01    0.000000E+00       7       0
      16    0.000000E+00    3.000000E+01    0.000000E+00       7       0
      17    1.000000E+01    3.000000E+01    0.000000E+00       0       0
      18    2.000000E+01    3.000000E+01    0.000000E+00       0       0
      19    3.000000E+01    3.000000E+01    0.000000E+00       0       0
      20    4.000000E+01    3.000000E+01    0.000000E+00       7       0
      21    0.000000E+00    4.000000E+01    0.000000E+00       7       0
      22    1.000000E+01    4.000000E+01    0.000000E+00       7       0
      23    2.000000E+01    4.000000E+01    0.000000E+00       7       0
      24    3.000000E+01    4.000000E+01    0.000000E+00       7       0
      25    4.000000E+01    4.000000E+01    0.000000E+00       7       0
     101    1.500000E+01    1.500000E+01    1.000000E+01       0       0
     102    2.500000E+01    1.500000E+01    1.000000E+01       0       0
     103    1.500000E+01    2.500000E+01    1.000000E+01       0       0
     104    2.500000E+01    2.500000E+01    1.000000E+01       0       0
$
$$$$$$$$  SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2       7       6
       2       1       2       3       8       7
       3       1       3       4       9       8
       4       1       4       5      10       9
       5       1       6       7      12      11
       6       1       7       8      13      12
       7       1       8       9      14      13
       8       1       9      10      15      14
       9       1      11      12      17      16
      10       1      12      13      18      17
      11       1      13      14      19      18
      12       1      14      15      20      19
      13       1      16      17      22      21
      14       1      17      18      23      22
      15       1      18      19      24      23
```

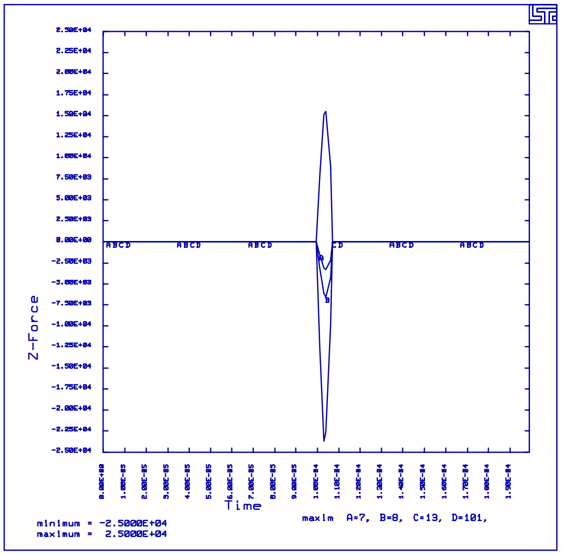
```
      16         1        19        20        25        24
     101         2       101       102       104       103
$
*END
```

Results:

```
taurus g=d3plot
19
udg 1 time 1.6e-4 rx -70 view
```



```
phs3
ncforc
oset -2.5e4 2.5e4 z-forc 7 8 13 101
```



LS-DYNA Manual Section: *CONTACT_ERODING_SURFACE_TO_SURFACE

Additional Sections:

*INITIAL_VELOCITY_GENERATION

Example: Projectile Penetrates Plate

Filename: contact.projectile.k

Description:

A projectile strikes a plate at a critical angle.

Model:

The hemispherical projectile has a length of 7.67 cm and a diameter of 0.767 cm. The plate measures 23.01 cm × 23 cm × 0.64 cm. The projectile and the plate are elastic perfectly plastic with failure strain. The initial velocity of the projectile is 0.129 cm/μsec at an angle of 75 degrees. The calculation terminates at 110.0 μsec.

Input:

The initial velocity (magnitude and direction) of the projectile is set using *INITIAL_VELOCITY_GENERATION. Eroding contact between the projectile surface and plate surface is defined so that the contact erodes as the element erodes (*CONTACT_ERODING_SURFACE_TO_SURFACE). This allows the contact to work correctly as layers of the parts erode during penetration.

Results:

The projectile fractures into a tip and trailing portion. The trailing portion punches a hole through the plate while the tip deflects off the plate.

*CONTACT_ERODING_SURFACE_TO_SURFACE

Projectile Penetrates Plate

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Projectile Penetrating Plate
$
$  LSTC Example
$
$  Last Modified: September 8, 1997
$
$   Units: gram, cm, microsec, 1e+07 N, Mbar, 1e+07 N-cm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 1.100E+02
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
       1.0
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 10.000000
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$          ieverp = 1 put each plot state in separate d3plot files
$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
      0.10
$
*DATABASE_MATSUM
$       dt
      0.10
$
```

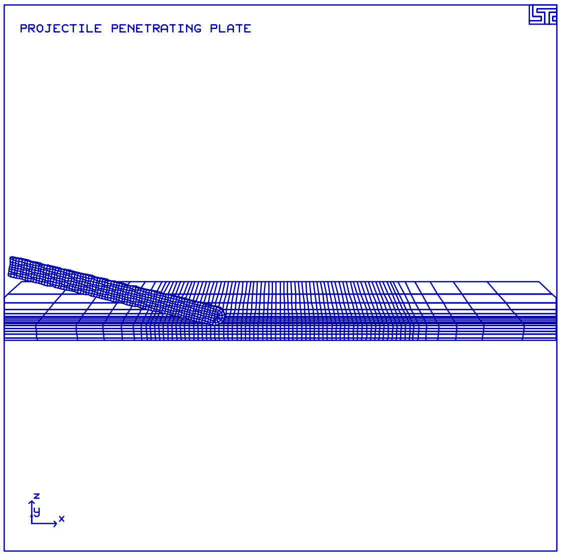
```
*DATABASE_RCFORC
$       dt
      0.10
$
*DATABASE_SLEOUT
$       dt
      0.10
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_ERODING_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2         3         3
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$     isym    erosop      iadj
         1         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Assign an initial velocity to the projectile (part 1) angled down
$$$$  towards the plate.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INITIAL_VELOCITY_GENERATION
$      sid      styp     omega        vx        vy        vz
         1         1           1.246E-01 0.000E+00-3.339E-02
$
$       xc        yc        zc        nx        ny        nz     phase

$
*SET_PART
         1
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Projectile
```

```
         1         1         1
Plate
         2         1         2
$
$
$$$$$$  Materials
$
$$$$  failure strain for erosion of the projectile and plate elements are
$$$$  set as:  fs = 0.8
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1 1.862E+01 1.170E+00      0.22 1.790E-02                 1.0
$      src       srp        fs
                           0.8
$

$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         2 7.896E+00 2.100E+00     0.284 1.000E-02                 1.0
$      src       srp        fs
                           0.8
$
$
$$$$$$  Sections
$
*SECTION_SOLID
$      sid    elform
         1         0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1    9.241751E+00   -1.534000E-05    5.137928E-02       2       6
       2    9.193813E+00    0.000000E+00    1.344095E-01       2       6
       3    9.145876E+00    0.000000E+00    2.174397E-01       2       6
       .
       ...  in total, 7668 nodes defined
       .
    7666    1.918446E+01    4.800000E+00    0.000000E+00       7       7
    7667    2.071067E+01    4.800000E+00    0.000000E+00       7       7
    7668    2.300000E+01    4.800000E+00    0.000000E+00       7       7
$
$$$$$  Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       1       2       5       4      10      11      14      13
       2       1       2       3       6       5      11      12      15      14
       3       1       4       5       8       7      13      14      17      16
       .
       ...  in total, 5664 solids defined
       .

    5662       2    7617    7618    7626    7625    7657    7658    7666    7665
    5663       2    7618    7619    7627    7626    7658    7659    7667    7666
```

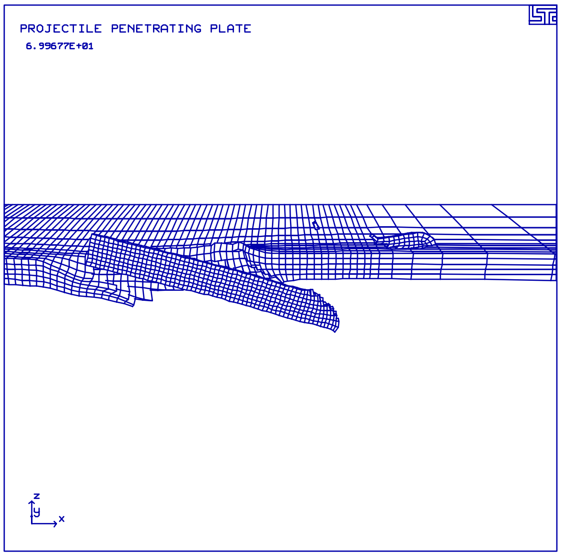
```
    5664        2     7619     7620     7628     7627     7659     7660     7668     7667
$
*END
```

Results:

```
taurus g=d3plot
19
rx -70 dist 27 view
```



```
state 8
m 1 center
dam view
```



LS-DYNA Manual Section: *CONTACT_NODES_TO_SURFACE

Additional Sections:

*CONSTRAINED_TIED_NODES_FAILURE

Example: Rigid Sphere Impacts a Plate at High Speed

Filename: contact.n2s-sphere.k

Description:

A sphere impacts a plate at high speed causing failure of the plate. This model can be used to show how different contacts can behave differently in a rather simple model. Instructions of this are explained in the header of the input deck.

Model:

A rigid sphere is made out of solid elements and given an initial velocity of 89 mm/ms towards a plate using the *DEFINE_BOX keyword. The plate is constructed out of shell elements. The shells of the plates do NOT have their nodes merged at common locations. Instead, tied nodes with failure constraints are used to connect the common nodes. This allows the plate to rupture and rip along seam lines instead of having elements fail (and being deleted) by using the more common failure criteria within the material definition.

Results:

The plate is definitely not made out of a bullet proof material.

*CONTACT_NODES_TO_SURFACE

Rigid Sphere Impacts a Plate at High Speed

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Rigid sphere dropped onto a plate
$
$  LSTC Example
$
$  Last Modified: September 4, 1997
$
$  * Part 2 - plate
$      Shells (2.5 mm thick)
$      Mild steel (with strain rate effect)
$      Constrained on all four edges
$      Connected using Tied Nodes with Failure Constraints
$
$  * Part 3 - sphere
$      Solids
$      Rigid
$      Initial Velocity: -89 mm/ms to all nodes of the sphere
$
$  * Contact: nodes (plate - 2) to surface (sphere - 3)  good   <== this file
$             nodes (sphere - 3) to surface (plate - 2)  bad
$
$  Note: For a really good demonstration of bad contact, remove all of the
$        *CONSTRAINED_TIED_NODES_FAILURE at the end of the deck and re-run
$        with the two contact definitions pointed out above.
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
      0.60         0       0.0       0.0       0.0
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       0.1
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$
$   cmpflg    ieverp    beamip
                   1
$
```

```
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
     0.005
$
*DATABASE_MATSUM
$       dt
     0.005
$
*DATABASE_NODOUT
$       dt
     0.005
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
      2633       362       489
$
*DATABASE_RBDOUT
$       dt
     0.005
$
*DATABASE_RCFORC
$       dt
     0.005
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Velocity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*INITIAL_VELOCITY
$
$     nsid    nsidex     boxid
                             5
$
$       vx        vy        vz        wx        wy        wz
       0.0       0.0     -89.0
$
*DEFINE_BOX
$
$    boxid       xmm       xmx       ymn       ymx       zmn       zmx
         5     -39.0      39.0     -39.0      39.0    -25.41      51.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - sliding interface definitions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_NODES_TO_SURFACE
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         2         3         3         3
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$
```

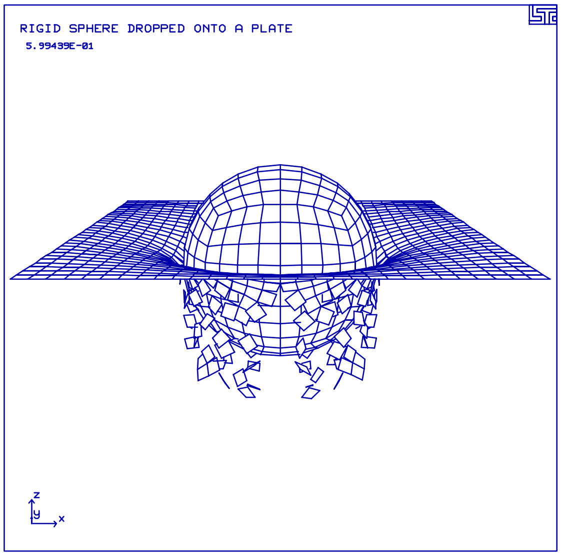
```
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$
$      pid       sid       mid     eosid      hgid      grav    adpopt
plate
         2         1         1
sphere
         3         2         2
$
$
$$$$  Materials
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 0.783E-05     200.0       0.3     0.207               0.750
$  Cowper/Symonds Strain Rate Parameters
$        c         p      lcss      lcsr
        40         5
$  Plastic stress/strain curves
     0.000     0.080     0.160     0.400     1.000
     0.207     0.250     0.275     0.290     0.300
$
$
*MAT_RIGID
$
$      mid        ro         e        pr         n    couple         m     alias
         2 0.783E-05     200.0       0.3
$
$      cmo      con1      con2

$
$   lco/a1        a2        a3        v1        v2        v3

$
$
$$$$  Sections
$
*SECTION_SHELL
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2                 3.0
$       t1        t2        t3        t4      nloc
      2.50      2.50      2.50      2.50
$
*SECTION_SOLID
$
$      sid    elform
         2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

```
$$$$  Boundary and Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Fix all the edge nodes of the plate with SPC's.
$
*BOUNDARY_SPC_NODE
$      nid       cid      dofx      dofy      dofz     dofrx     dofry     dofrz
       773         0         1         1         1         1         1         1
       774         0         1         1         1         1         1         1
       .
       ...  in total, 236 SPC's defined
       .
      4371         0         1         1         1         1         1         1
      4372         0         1         1         1         1         1         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
       1 -2.19971620E+01 -2.19971620E+01 -9.29716200E+00       0       0
       2 -2.41208560E+01 -2.41208560E+01 -4.26999400E+00       0       0
       .
       ...  in total, 4372 nodes defined
       .
    4371 7.619873000E+01 -7.61987300E+01 -2.54254000E+01       0       0
    4372 7.619873000E+01 -7.11212700E+01 -2.54254000E+01       0       0
$
$$$$$  Elements - Solids
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       3       1      46      51       6       2      47      52       7
       2       3       6      51      56      11       7      52      57      12
       .
       ...  in total, 384 solids defined
       .
     383       3     748     769     772     751     557     558     560     559
     384       3     751     772     674     671     559     560     562     561
$
$$$$$  Elements - Shells
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       2     773     774     775     776
       2       2     777     778     779     780
       .
       ...  in total, 900 shells defined
       .
     899       2    4365    4366    4367    4368

     900       2    4369    4370    4371    4372
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

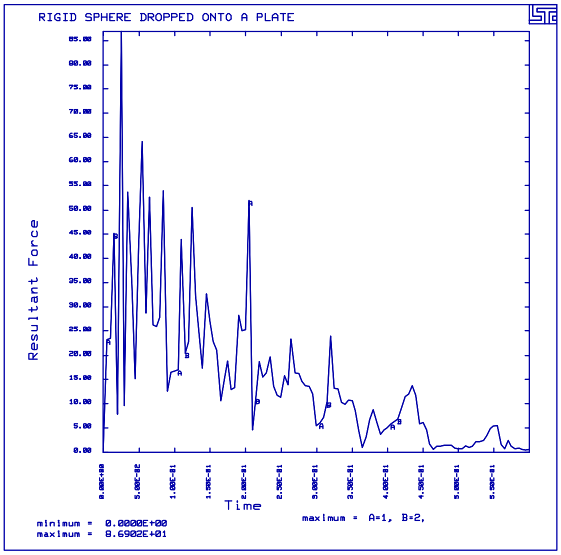
```
$
$$$$  Define Tied Nodes with Failure Constraints
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Tie all the adjacent corners of the shells together.  Essentially, do
$$$$  a merge by way of tied nodes with failure.
$
*CONSTRAINED_TIED_NODES_FAILURE
$     nsid      eppf
       101    0.0850
$
*SET_NODE_LIST
$      sid
       101
       775       778       896       897
$
  .
  ...  in total, 841 CONSTRAINED_TIED_NODES_FAILURE/SET_NODE_LIST pairs defined
  .
$
*CONSTRAINED_TIED_NODES_FAILURE
$     nsid      eppf
       941    0.0850
*SET_NODE_LIST
$      sid
       941
      4247      4250      4368      4369
*END
```

Results:

taurus g=d3plot
state 7 center
rx -75 view



phs3
rcforc
result



LS-DYNA Manual Section: *CONTACT_SINGLE_EDGE

Additional Sections:

*CONTACT_FORCE_TRANSDUCER_PENALTY

Example: Corrugated Sheet Contacts Edges

Filename: contact.edge.k

Description:

A corrugated plate strikes a flat plate from opposite directions.

Input:

The model consists of 135 elastic plastic Belytschko-Tsay shell elements. The interaction of the two structures is to edge contact (*CONTACT_SINGLE_EDGE). A contact force transducer is defined to moniter the forces of the contact in the ascii file rcforc. The nodes on the upper corrugated plate have an initial velocity of 10 meters/second.

Results:

A contour plot of the effective-stress and a plot of the forces from the ascii file rcforc illustrate that the plates are in contact.

Reference:

Stillman, D. W.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Edge to Edge Contact with Force Transducer
$
$  LSTC Example
$
$  Last Modified: September 9, 1997
$
$  Units: kg, m, s, N, Pa, Joule
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     0.050
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
     0.001
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 9.990E+02
$
*DATABASE_GLSTAT
$       dt
     0.001
$
*DATABASE_MATSUM
$       dt
     0.001
$
*DATABASE_RCFORC
$       dt
     0.001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  Type 22, single edge contact
$
*CONTACT_SINGLE_EDGE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1                   0         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt
```

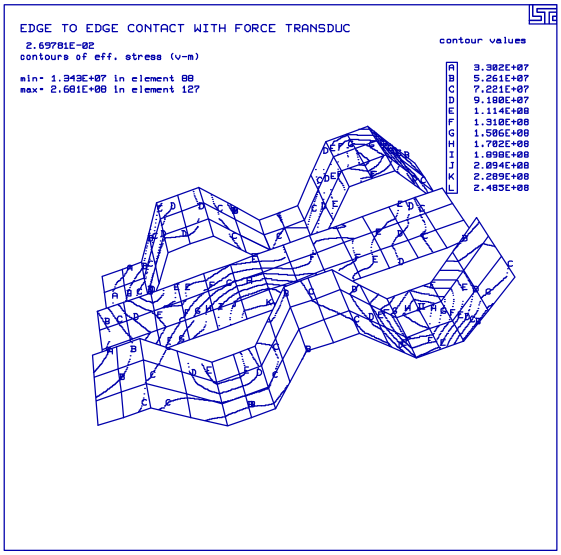
```
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*SET_SEGMENT
$      sid
         1
$       n1        n2        n3        n4
         1         2         0         0
         2         3         0         0
         3        13         0         0
        13        14         0         0
        14        21         0         0
        21        22         0         0
        22        29         0         0
        29        30         0         0
        30        37         0         0
        37        38         0         0
        38        45         0         0
        45        46         0         0
        46        53         0         0
        53        54         0         0
        54        61         0         0
        61        62         0         0
        69        70         0         0
        70        71         0         0
        71        72         0         0
        72        73         0         0
        73        74         0         0
        74        75         0         0
        75        76         0         0
        76        77         0         0
        77        78         0         0
        78        79         0         0
        79        80         0         0
        80        81         0         0
        81        82         0         0
       111       112         0         0
       112       113         0         0
       113       114         0         0
       114       115         0         0
       115       116         0         0
       116       117         0         0
       117       118         0         0
       118       119         0         0
       119       120         0         0
       120       121         0         0
       121       122         0         0
       122       123         0         0
       123       124         0         0
       125       126         0         0
       126       127         0         0
       127       137         0         0
       137       138         0         0
       138       145         0         0
       145       146         0         0
       146       153         0         0
       153       154         0         0
       154       161         0         0
       161       162         0         0
       162       169         0         0
       169       170         0         0
       170       177         0         0
       177       178         0         0
```

```
      178       185         0         0
      185       186         0         0
$
$
$$$$  Force transducer defined to calculate contact forces on part 1.
$
*CONTACT_FORCE_TRANSDUCER_PENALTY
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$     ssid      msid     sstyp     mstyp
         5                   2


$
*SET_PART_LIST

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
         5
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes of the part 1 (node set id = 2) are given an initial velocity
$$$$  in the y-direction of 10 m/s.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
         2
$       vx        vy        vz       vxr       vyr       vzy
       0.0      10.0       0.0       0.0       0.0       0.0
$
*SET_NODE_LIST
$      sid
         2
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
         1         2         3         4         5         6         7         8
         9        10        11        12        13        14        15        16
        17        18        19        20        21        22        23        24
        25        26        27        28        29        30        31        32
        33        34        35        36        37        38        39        40
        41        42        43        44        45        46        47        48
        49        50        51        52        53        54        55        56
        57        58        59        60        61        62        63        64
        65        66        67        68
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
plate-1
         1         1         1
plate-2
         2         1         1
plate-3
```

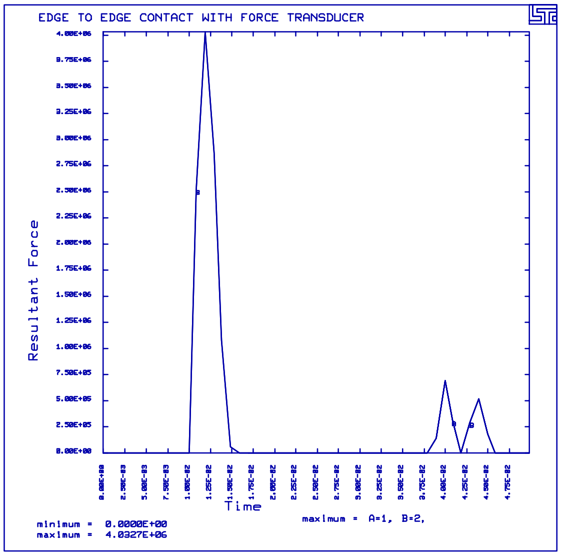
```
         3         1         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1   7.85e+3 200.0e+09     0.300   2.0e+09
$      src       srp        fs
       0.0       0.0       0.0
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1
$       t1        t2        t3        t4      nloc
 2.000E-03 2.000E-03 2.000E-03 2.000E-03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00   -1.000000E-01    1.500000E+00       0       0
       2    1.250000E+00   -1.000000E-01    1.500000E+00       0       0
       3    2.500000E+00   -1.000000E-01    1.500000E+00       0       0
       .
       ...  in total, 192 nodes defined
       .
     190    2.000000E+01    6.766667E+00   -1.500000E+00       0       0
     191    1.875000E+01    8.100000E+00    5.000000E-01       0       0
     192    2.000000E+01    8.100000E+00   -1.500000E+00       0       0
$
$$$$$$$$  SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       4       5       2
       2       1       2       5       6       3
       3       1       4       7       8       5
       .
       ...  in total, 135 shells defined
       .
     133       3     187     189     190     188
     134       3     182     184     191     189
     135       3     189     191     192     190
$
*END
```

Results:

```
taurus g=d3plot
19
rx -40 rz 20 s 28 mono numc 12 contour 9
```



```
phs3
rcforc
resultant
```



LS-DYNA Manual Section: *CONTACT_TIED_NODES_TO_SURFACE

Example: Discrete Nodes Tied to a Surface

Filename: contact.tied_nodes.box.k

Description:

A shell element drops onto and then rebounds from, a hollow box that is tied to an elastic plate.

Model:

The plate measures 40 × 40 × 1 mm^3 and contains 16 Belytschko-Tsay shell elements. The dropped shell element has a side length of 10 mm, a thickness of 2 mm and a drop height of 10 mm. The box contains 12 Belytschko-Tsay shell elements. All shell element materials are elastic. The initial velocity of the shell elements is 100,000 mm/second. The calculation terminates at 0.002 seconds.

Input:

The nodes of the dropped shell are given an initial velocity (*INITIAL_VELOCITY). The nodes on the bottom of the box, those facing the plate, are tied to the plate (*CONTACT_TIED_NODES_TO_SURFACE). Automatic single surface contact is used to define the contact between the dropped shell and the box.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

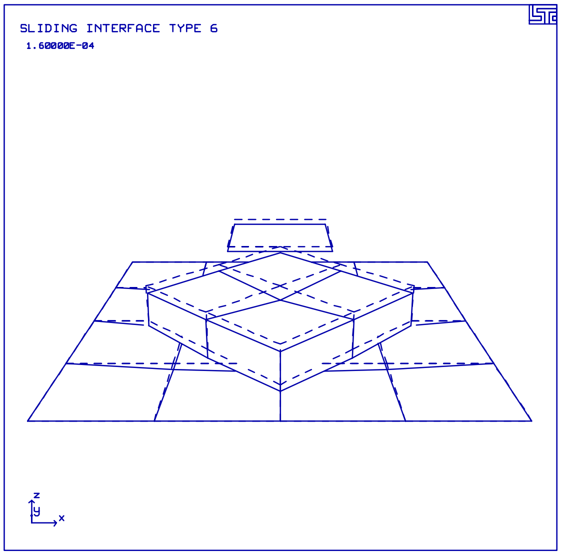
```
*KEYWORD
*TITLE
Sliding Interface Type 6
$
$  LSTC Example
$
$  Last Modified: September 5, 1997
$
$  A box is tied to a bottom plate with tied nodes to surface contact.
$  This box is impacted by a shell element, which has an initial velocity.
$
$  Units: mm, s
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 0.200E-03
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 0.010E-03
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 .0005E-03
$
$
*DATABASE_NODOUT
$       dt
 .0010E-03
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
       101        13       213
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
```

```
$
$
$$$$$$$$   The nodes on the bottom of the box (part 2) are tied to
$$$$$$$$   the bottom plate (part 1).
$
*CONTACT_TIED_NODES_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         2         1         4         3                             1         1

$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         2
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       201       202       203       204       206       207       208       209
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes of the dropped shell are given an initial velocity.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
         3
$       vx        vy        vz
       0.0       0.0 -100000.0       0.0       0.0       0.0
$
*SET_NODE_LIST
$      sid
         3
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       101       102       103       104
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
bottom plate
         1         1         1
dropped shell
         2         2         1
box
         3         1         1
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1  1.00e-08   100000.     0.300
$
```

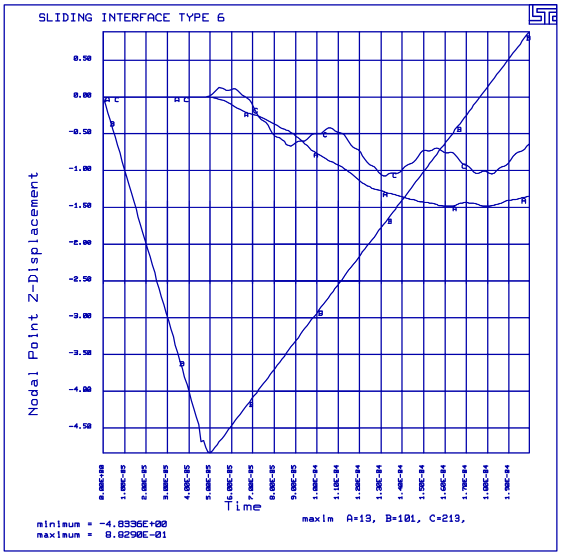
```
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333         2
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2             0.83333         2
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Outer edge nodes of the bottom plate (part 1)
$$$$  are fixed in translation (tc = 7)
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       0
       2    1.000000E+01    0.000000E+00    0.000000E+00       7       0
       3    2.000000E+01    0.000000E+00    0.000000E+00       7       0
       .
       ...  in total, 48 nodes defined
       .
     217    5.867900E+00    2.000000E+01    4.000000E+00       0       0
     218    1.292890E+01    2.707110E+01    4.000000E+00       0       0
     219    2.000000E+01    3.414210E+01    4.000000E+00       0       0
$
$$$$$$$$  SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2       7       6
       2       1       2       3       8       7
       3       1       3       4       9       8
       .
       ...  in total, 29 shells defined
       .
     210       3     212     213     216     215
     211       3     214     215     218     217
     212       3     215     216     219     218
$
*END
```

Results:

taurus g=d3plot
19
udg 1 time 1.6e-4 rx -70 view



phs3
nodout
grid z-disp



LS-DYNA Manual Section: *CONTACT_ENTITY

Additional Sections:

*BOUNDARY_PRESCRIBED_MOTION_RIGID

Example: Rigid Sphere Impacts Plate

Filename: contact_entity.sphere.k

Description:

A rigid sphere drops onto an elastic plate. The sphere contains shell elements automatically generated with a “Geometric Contact Entity” spherical surface.

Model:

The plate of elastic material measures 40 × 40 × 2 mm^3 and contains 64 Belytschko-Tsay shell elements. The sphere has a radius of 6.0 mm and the distance from the center of the cube to the plate is 8.5 mm. The inertia properties of the sphere are defined by the properties of the rigid brick element. A geometric contact entity defines the spherical contact surface. The sphere moves toward the plate with a uniform motion. The termination time is 0.0005 seconds.

Input:

The Geometric Contact Entity defines the outer master surface on the rigid sphere (*CONTACT_ENTITY). The nodes on the plate are slave nodes (*SET_NODE_LIST) , and are in the “Geometric Entity”. A load curve definition defines the movement of the sphere (*BOUNDARY_PRESCRIBED_MOTION_RIGID, *DEFINE_CURVE). The displacement condition for rigid bodies is input by part number, not by listing the nodes included in the definition.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Geometric Contact Entity
$
$  LSTC Example
$
$  * Part 1 - plate
$      Shells (2.0 mm thick)
$      elastic material
$      translational constraints on all four edges (z-dir only)
$
$  * Part 2 - sphere  -  Contact Entity
$      Defined as shells and rigid material but really there are no part 2
$        elements defined explicitly.  The contact entity is really part 2.
$      center (x,y,z) = (20,20,9)
$      radius = 6 mm
$
$
$  ===> Due to the course mesh of the plate, there is considerable amount
$         of penetration of the sphere into the plate.
$
$  Last Modified: April 10, 1997
$
$  Units: mm, ton, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control/Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
  .5000E-3
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                 0.1
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
 0.0200E-3
$
*DATABASE_RBDOUT
$  dt/cycl      lcdt
  0.005e-3
$
*DATABASE_GCEOUT
$  dt/cycl      lcdt
  0.005e-3
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

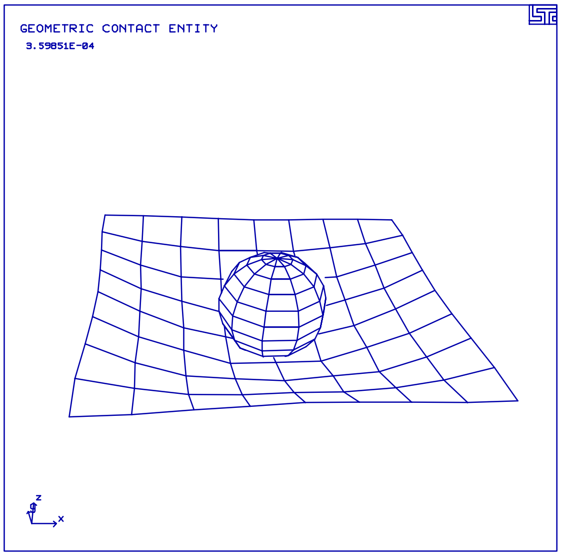
```
$$$$  Contact Entity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_ENTITY
$      pid    geotyp       sid      styp        sf        df        cf    intord
         2         2         1         0       1.0
$
$       bt        dt        so

$
$       xc        yc        zc        ax        ay        az
      0.00      0.00       .00      1.00      0.00      0.00
$
$       bx        by        bz
      0.00      1.00      0.00
$
$    inout        g1        g2        g3        g4        g5        g6        g7
         0     20.00     20.00      9.00      6.00
$
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         1
$
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
         1         2         3         4         5         6         7         8
         9        10        11        12        13        14        15        16
        17        18        19        20        21        22        23        24
        25        26        27        28        29        30        31        32
        33        34        35        36        37        38        39        40
        41        42        43        44        45        46        47        48
        49        50        51        52        53        54        55        56
        57        58        59        60        61        62        63        64
        65        66        67        68        69        70        71        72
        73        74        75        76        77        78        79        80
        81
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$ Part    1    shell: plate  - elastic material
$
$$$ Part    2    solid: sphere - rigid material  ==> contact entity
$
*PART
plate
$      pid       sid       mid     eosid      hgid    adpopt
         1         1         1         0         0         0
$
*PART
sphere
$      pid       sid       mid     eosid      hgid    adpopt
         2         2         2         0         0         0
$
$
```

```
$$$$  Materials
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1  2.00e-08   100000.     0.300
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2  2.00e-08   100000.     0.300                             4
$
$      cmo      con1      con2

$
$   lco/a1        a2        a3        v1        v2        v3

$
$
$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333       2.0       3.0
$
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
*SECTION_SOLID
$      sid    elform
         2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary and Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      mid       dof       vad      lcid        sf       vid
         2         3         2         1 1.000E+00
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$           abscissa            ordinate
                 0.0                 0.0
              0.0050              -150.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc

       1    0.000000E+00    0.000000E+00    0.000000E+00       3       0
       2    5.000000E+00    0.000000E+00    0.000000E+00       3       0
```

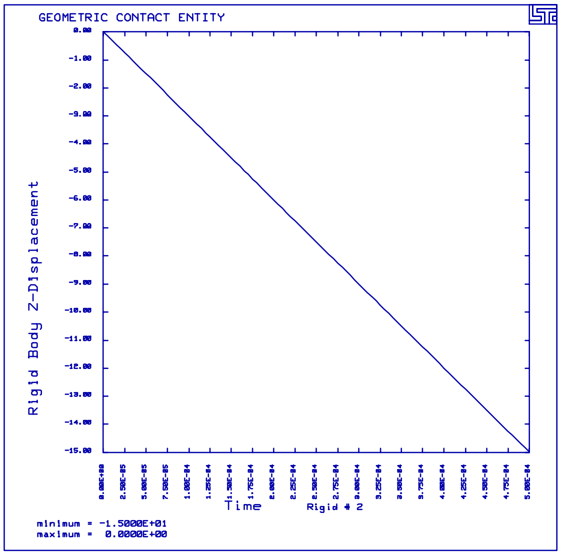
```
       3    1.000000E+01    0.000000E+00    0.000000E+00       3       0
       .
       ...  in total, 81 nodes defined
       .
      79    3.000000E+01    4.000000E+01    0.000000E+00       3       0
      80    3.500000E+01    4.000000E+01    0.000000E+00       3       0
      81    4.000000E+01    4.000000E+01    0.000000E+00       3       0
$
$$$$$  Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2      11      10
       2       1       2       3      12      11
       3       1       3       4      13      12
       .
       ...  in total, 64 shells defined
       .
      62       1      69      70      79      78
      63       1      70      71      80      79
      64       1      71      72      81      80
$
*END
```

Results:

```
taurus g=d3plot
19
rx -60 ry 10 ytrans 5 s 19 view
```



```
phs3
rbdout
oset -15 0 z-disp
```



LS-DYNA Manual Section: *CONTROL_CONTACT

Additional Sections:

*LOAD_SEGMENT
*MAT_POWER_LAW_PLASTICITY
*RIGIDWALL_PLANAR

Example: Hemispherical Punch

Filename: control_contact.hemi-draw.k

Description:

This problem includes three tools a punch, a pressure pad, a die and a workpiece. A workpiece is deep drawn by the hemispherical punch while the pressure pad and die prevents wrinkling. The load on the pressure pad is ramped, then the punch displaces in the y direction.

Model:

The workpiece measures 80 mm in radius and 1 mm in thickness. The punch radius is 50.0 mm and the die torus radius is 6.35 mm. The workpiece contains 528 Belytschko Tsay shell elements with 5 integration points through the thickness. The tools are rigid members. Only 1/4 of the system is modeled because of symmetry.

Input:

The number of integration points is 5 for the workpiece. (*SECTION_SHELL) This model contains two options to consider shell thickness. The first option is the contact surfaces are projected to the true surface of shell (*CONTROL_CONTACT). The second option is membrane straining results in thickness changes (*CONTROL_CONTACT). The motion of the punch follows a sine function represented by load curve number 2 (Section 22).

Reference:

Honecker, A. and Mattiason, K.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Hemispherical Deep Draw
$
$  LSTC Example
$
$  Last Modified: September 10, 1997
$
$  Units: kg, mm, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
       6.0
$
$$$$   shell thickness is considered during contact: shlthk = 1
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
                 1.0                   1
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3         0         0                   2      1000
$
$$$$   membrane straining causes thickness change: istupd = 1
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                       1
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
      0.20
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 12.00E+00
$
*DATABASE_GLSTAT
```

```
$       dt
      0.05
$
*DATABASE_MATSUM
$       dt
      0.05
$
*DATABASE_NODOUT
$       dt
      0.05
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
      1333
$
*DATABASE_RCFORC
$       dt
      0.05
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$$$$$$  contact between workpiece and punch
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2         3         3
$       fs        fd        dc        vc       vdc    penchk        bt        dt
      0.15      0.15
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$  contact between workpiece and holder
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         3         3         3
$       fs        fd        dc        vc       vdc    penchk        bt        dt
      0.15      0.15
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$  contact between workpiece and die
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         4         3         3
$       fs        fd        dc        vc       vdc    penchk        bt        dt
      0.15      0.15
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Workpiece
         1         1         1
Punch
         2         1         2
Holder (pressure pad)
         3         1         2
Die
         4         1         2
$
$
*MAT_POWER_LAW_PLASTICITY

$      mid        ro         e        pr         k         n       src       srp
         1  7.83e-06      69.0     0.300     0.598     0.216       0.0       0.0
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2  7.83e-06      69.0     0.300
$      cmo     con1       con2

$   lco/a1        a2        a3        v1        v2        3

$
$$$$$  All parts use this section, thus all shells have 1 mm thicknesses.
$$$$$  Those parts that aren't rigid, use B-T shell formulation with
$$$$$  five through the thickness integration points.
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2                   5
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0       0.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$  Define motion of the punch.
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      pid       dof       vad      lcid        sf       vid
         2         2         0         2      -1.0         0
$
$$$$$  Pressure load on the holder.
$
*LOAD_SEGMENT
$     lcid        sf        at        n1        n2        n3        n4
         1 1.000E+00 0.000E+00       907       900       901       908
         1 1.000E+00 0.000E+00       914       907       908       915
         1 1.000E+00 0.000E+00       921       914       915       922
       .
       ...  in total, 144 segments defined
       .
```

```
         1 1.000E+00 0.000E+00      1059      1052      1053      1060
         1 1.000E+00 0.000E+00      1066      1059      1060      1067
         1 1.000E+00 0.000E+00      1073      1066      1067      1074
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigidwalls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$$  Prevent nodes on the holder from moving in the positive y-direction.
$
*RIGIDWALL_PLANAR
$     nsid    nsidex     boxid
         1
$       xt        yt        zt        xh        yh        zh      fric
     0.000     0.000     0.000   0.00000   1.00000   0.00000     0.000
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       900       901       902       903       904       905       906       907
       908       909       910       911       912       913       914       915
       916       917       918       919       920       921       922       923

       924       925       926       927       928       929       930       931
       932       933       934       935       936       937       938       939
       940       941       942       943       944       945       946       947
       948       949       950       951       952       953       954       955
       956       957       958       959       960       961       962       963
       964       965       966       967       968       969       970       971
       972       973       974       975       976       977       978       979
       980       981       982       983       984       985       986       987
       988       989       990       991       992       993       994       995
       996       997       998       999      1000      1001      1002      1003
      1004      1005      1006      1007      1008      1009      1010      1011
      1012      1013      1014      1015      1016      1017      1018      1019
      1020      1021      1022      1023      1024      1025      1026      1027
      1028      1029      1030      1031      1032      1033      1034      1035
      1036      1037      1038      1039      1040      1041      1042      1043
      1044      1045      1046      1047      1048      1049      1050      1051
      1052      1053      1054      1055      1056      1057      1058      1059
      1060      1061      1062      1063      1064      1065      1066      1067
      1068      1069      1070      1071      1072      1073      1074
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Curves
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$                   a                   o
           0.000E+00           0.000E+00
           1.000E+00           1.000E-03
           8.000E+00           1.000E-03
$
*DEFINE_CURVE
```

```
$     lcid      sidr      scla      sclo      offa      offo
         2
$                  a                   o
         0.000E+00           0.000E+00
         1.000E+00           0.000E+00
         1.125E+00           1.479E+00
         1.250E+00           2.949E+00
         1.375E+00           4.400E+00
         1.500E+00           5.825E+00
         1.625E+00           7.213E+00
         1.750E+00           8.558E+00
         1.875E+00           9.849E+00
         2.000E+00           1.108E+01
         2.125E+00           1.224E+01
         2.250E+00           1.333E+01
         2.375E+00           1.433E+01
         2.500E+00           1.525E+01
         2.625E+00           1.607E+01
         2.750E+00           1.680E+01
         2.875E+00           1.741E+01
         3.000E+00           1.793E+01
         3.125E+00           1.833E+01
         3.250E+00           1.862E+01
         3.375E+00           1.879E+01
         3.500E+00           1.885E+01
         3.625E+00           1.879E+01
         3.750E+00           1.862E+01
         3.875E+00           1.833E+01
         4.000E+00           1.793E+01
         4.125E+00           1.741E+01
         4.250E+00           1.680E+01
         4.375E+00           1.607E+01
         4.500E+00           1.525E+01
         4.625E+00           1.433E+01
         4.750E+00           1.333E+01
         4.875E+00           1.224E+01
         5.000E+00           1.108E+01
         5.125E+00           9.849E+00
         5.250E+00           8.558E+00
         5.375E+00           7.213E+00
         5.500E+00           5.825E+00
         5.625E+00           4.400E+00
         5.750E+00           2.949E+00
         5.875E+00           1.479E+00
         6.000E+00           0.000E+00
         8.000E+00           0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$$  Note: Boundary conditions on many of the nodes are defined here.
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       6       7
       2    5.833342E+00    0.000000E+00    0.000000E+00       3       4
       3    1.166667E+01    0.000000E+00    0.000000E+00       3       4
       .
       ...  in total, 1599 nodes defined
       .
```

```
    1597    0.000000E+00   -5.000533E-01   -7.462286E+01       7       7
    1598    0.000000E+00   -5.000534E-01   -7.771143E+01       7       7
    1599    0.000000E+00   -5.000535E-01   -8.080000E+01       7       7
$
$$$$$$$$  SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       8       9       2
       2       1       2       9      10       3
       3       1       3      10      11       4
       .
       ...  in total, 1452 shells defined
       .
    1450       4    1589    1596    1597    1590
    1451       4    1590    1597    1598    1591
    1452       4    1591    1598    1599    1592
*END
```

Results:

```
taurus g=d3plot
19
rx 10 rayz view
```

```
restore rx 10 state 23 explode 1 0 -20 0 1
explode 1 0 10 0 3
explode 1 0 20 0 4 rayz view
```

LS-DYNA Manual Section: *CONTROL_DAMPING

Additional Sections:

*DAMPING_GLOBAL
*DATABASE_CROSS_SECTION_SET
*LOAD_NODE_SET

Example: Cantilever Beam

Filename: control_damping.beam.k

Description:

A cantilever beam is subjected to a load at the free end. The beam then vibrates relative to the equilibrium position without damping in case 1 and with damping in case 2.

Model:

The beam measures 1000 × 100 × 10 mm^3 and is modeled by 10 Belytschko-Tsay shell elements. A force of 100 N is applied in the z-direction at the free end. The calculation ends at 0.5 seconds.

Input for the undamped system:

The force at the free end is applied as two point forces. The size of these forces is controlled by load curve definition number 1 (*DEFINE_CURVE, *LOAD_NODE_SET). The ASCII-files contain information for section force data, nodal information, and shell element information. Data from ASCII-files can be processed in phase 3 of LS-TAURUS.

Input for the damped system:

The same input as in the undamped case except for a global damping constant (*DAMPING_GLOBAL, *CONTROL_DAMPING).

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Cantilever Beam with Damping
$
$  LSTC Example
$
$  Last Modified: September 11, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Damping
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DAMPING_GLOBAL
$     lcid    valdmp
         0       0.0
$
$$$$  for damping of 10
$
$*DAMPING_GLOBAL
$         0      10.0
$
$$$$  for damping of 50
$
$*DAMPING_GLOBAL
$         0      50.0
$
*CONTROL_DAMPING
$   nrcyck     drtol    drfctr    drterm    tssfdr    irelal     edttl    idrflg
       100    1.0e-3     0.995                 0.9
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
    0.5001
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
       0.1
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_HOURGLASS
$      ihq        qh
```

```
         4
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         0         0         0         0                   2      1000
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                        1
$   cmpflg    ieverp    beamip

$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
     0.020
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_ELOUT
$       dt
     0.001
$
*DATABASE_HISTORY_SHELL
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
*DATABASE_GLSTAT
$       dt
     0.001
$
*DATABASE_NODOUT
$       dt
     0.001
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
        21
$
*DATABASE_SECFORC
$       dt
     0.001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Cross Sections
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$$  define a cross section through the beam to monitor force & moment
$
*DATABASE_CROSS_SECTION_SET
$     nsid      hsid      bsid      ssid      tsid      dsid
         1                             1
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
         1         2
$
```

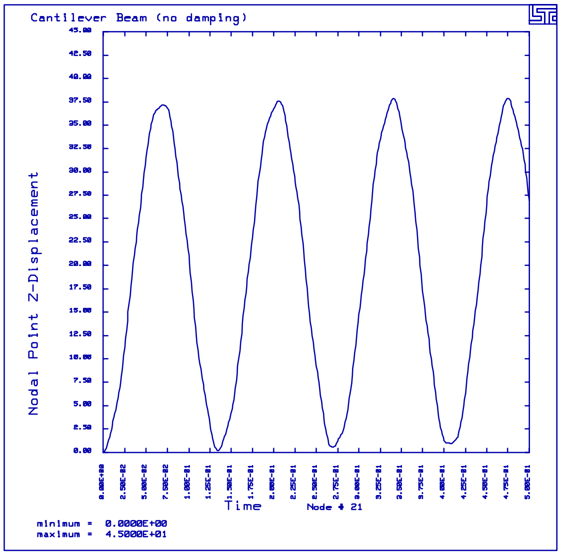
```
*SET_SHELL_LIST
$      sid       da1       da2       da3       da4
         1
$     eid1
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Load nodes 21 and 22 with a constant 50 N in the z-direction.
$
*LOAD_NODE_SET
$     nsid       dof      lcid        sf       cid        m1        m2        m3

         2         3         1       0.5
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         2
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
        21        22
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$                 a                   o
               0.0               100.0
              10.0               100.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Beam - Elastic Material
         1         1         1
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1  1.00e-08  210000.0     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2       1.0         2       1.0
$       t1        t2        t3        t4      nloc
      10.0      10.0      10.0      10.0       0.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$$$$  Nodes 1 and 2 have fixed boundary conditions (translation and rotation).
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       2    0.000000E+00    1.000000E+02    0.000000E+00       7       7
       3    1.000000E+02    0.000000E+00    0.000000E+00       0       0
       .
       ...  in total, 22 nodes defined
       .
      20    9.000000E+02    1.000000E+02    0.000000E+00       0       0
      21    1.000000E+03    0.000000E+00    0.000000E+00       0       0
      22    1.000000E+03    1.000000E+02    0.000000E+00       0       0
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       3       4       2
       2       1       3       5       6       4
       3       1       5       7       8       6
       4       1       7       9      10       8
       5       1       9      11      12      10
       6       1      11      13      14      12
       7       1      13      15      16      14
       8       1      15      17      18      16
       9       1      17      19      20      18
      10       1      19      21      22      20
$
*END
```

Results:

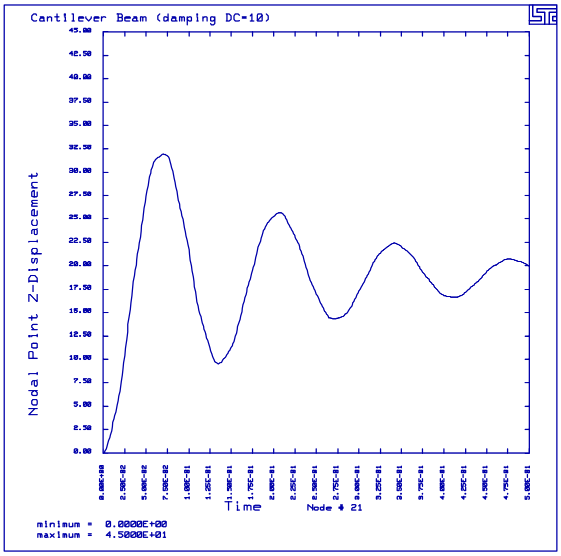
```
taurus g=d3plot
rx -40 head Cantilever Beam (no damping)
time 0.2 udg 1 view
```

```
phs3 nodout
head Cantilever Beam (no damping)
oset 0 45 z-disp
```

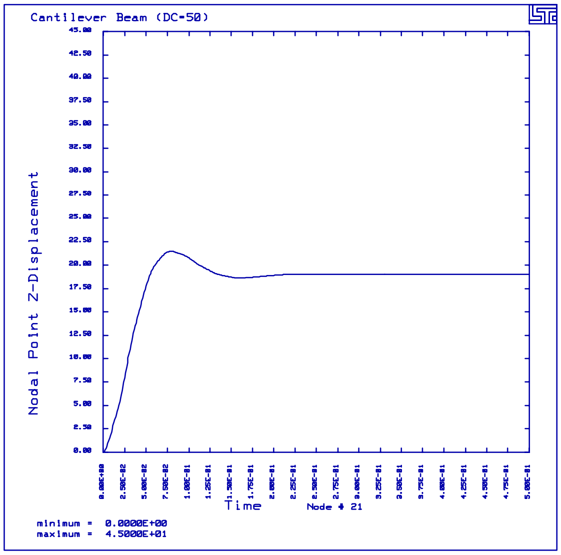


Results:

from phase 3, nodout - damping of DC = 10



from phase 3, nodout - damping of DC = 50



LS-DYNA Manual Section: *CONTROL_ENERGY

Example: Bar Impact

Filename: control_energy.bar-impact.k

Description:

A copper bar strikes a wall.

Model:

A 1/4 symmetry bar measures 0.32 cm in radius and 3.24 cm in length and contains 972 hexahedron element. The bar starts at 0.0227 cm/μsec and stops at 0 cm/μsec. The calculation illustrates the energy balance where E = KE + IE + HGE.

Input:

The hourglass energy is computed at a negligible cost. (*CONTROL_ENERGY) The initial velocity for every node is set to -0.0227 except the nodes at z = 0.

Results:

The undeformed and deformed shape of the bar are shown. The total, kinetic, internal and hourglass energies are also shown.

List of LS-DYNA input deck:

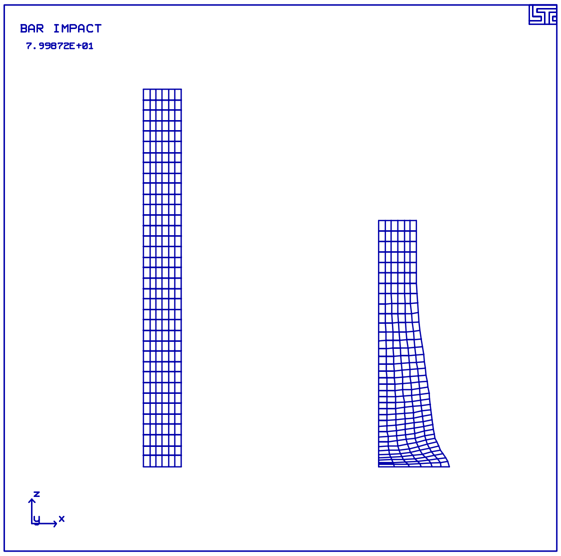
```
*KEYWORD
*TITLE
bar impact
$
$  LSTC Example
$
$  Last Modified: September 12, 1997
$
$  Units: gm, cm, microsec, 1e+07 N, Mbar, 1e+07 N-cm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     82.10
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         0         0         0         0                   2      1000
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       5.0
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
       1.0
$
*DATABASE_GLSTAT
$       dt
       0.5
$
*DATABASE_NODOUT
$  dt/cycl      lcdt
       0.5
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
      1333
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Nodes within box 2 are given an initial velocity in the neg z-direction.
$$$$  These are all the nodes except for those on the bottom of the bar.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
         0         0         2
$       vx        vy        vz       vxe       vye       vze
       0.0       0.0   -0.0227       0.0       0.0       0.0
$
*DEFINE_BOX
$    boxid       xmm       xmx       ymn       ymx       zmn       zmx
         2     -1.e6      1.e6     -1.e6      1.e6  0.50e-02      1.e6
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Bar
         1         1         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1     8.930      1.17     0.350     0.004     0.001       1.0
$      src       srp        fs
       0.0       0.0       0.0
$
$
*SECTION_SOLID
$      sid    elform
         1         0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Many nodes have boundary conditions to simulate symmetry.
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       2    5.330000E-02    0.000000E+00    0.000000E+00       5       7
       3    1.067000E-01    0.000000E+00    0.000000E+00       5       7
       .
       ...  in total, 1369 nodes defined
       .
    1367    0.000000E+00    2.133000E-01    3.240000E+00       1       7
    1368    0.000000E+00    2.667000E-01    3.240000E+00       1       7
    1369    0.000000E+00    3.200000E-01    3.240000E+00       1       7
$

$$$$$  Solid Elements
```

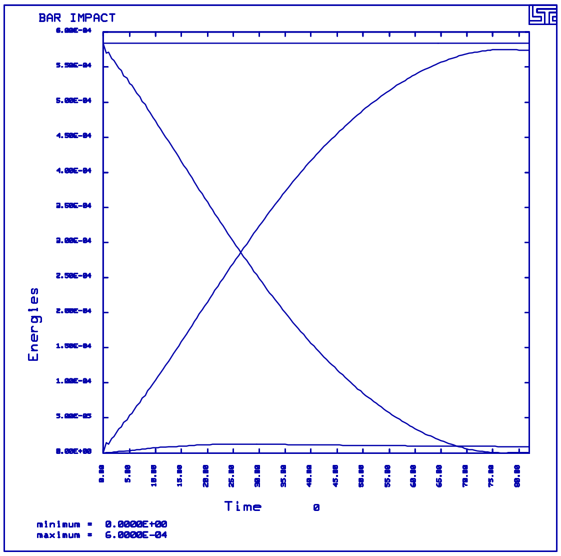
```
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       8       1       2       9      45      38      39      46
       2       1       9       2       3      10      46      39      40      47
       3       1      10       3       4      11      47      40      41      48
       .
       ...  in total, 972 solids defined
       .
     970       1    1317    1318    1327    1330    1354    1355    1364    1367
     971       1    1330    1327    1328    1331    1367    1364    1365    1368
     972       1    1331    1328    1329    1332    1368    1365    1366    1369
$
*END
```

Results:

```
taurus g=d3plot
19
rx -90 angle 1 xtrans -1 view xtrans 2 state 17 over view
```



```
phs3 glstat
oset 0 6e-4 otxt Energies
total over kine over inter over hour
```



LS-DYNA Manual Section: *CONTROL_SHELL

Example: Hemispherical Load

Filename: control_shell.hemi-load.k

Description:

A spherical shell is subjected to outward point loads on the x-axis and inward point loads on the z-axis.

Model:

The 1/8 symmetry model of a sphere measures 10 inches in radius with a thickness of 0.04 inches. The model contains 48 shell elements. A force of one pound is applied in the positive x-direction to the node on the x-axis. A force of one pound is applied in the negative z-direction to the node on the y-axis.

Input:

The element formulation is the Hughes-Liu shell with four integration points through the thickness. Note: If B-T element formulation is used the solution would be incorrect. To fix it, the Belytschko Tsay shell requires the Belytschko-Wang-Chiang warpage stiffness modification (*CONTROL_SHELL). The concentrated loads are applied to two nodes (*DEFINE_CURVE, *LOAD_NODE_POINT).

Results:

The oscillation of the node on the z-axis shows a regular oscillatory behavior. Since there is no specified damping, oscillations would be expected.

Reference:

Belytschko, T., Wang and Chiang.

List of LS-DYNA input deck:

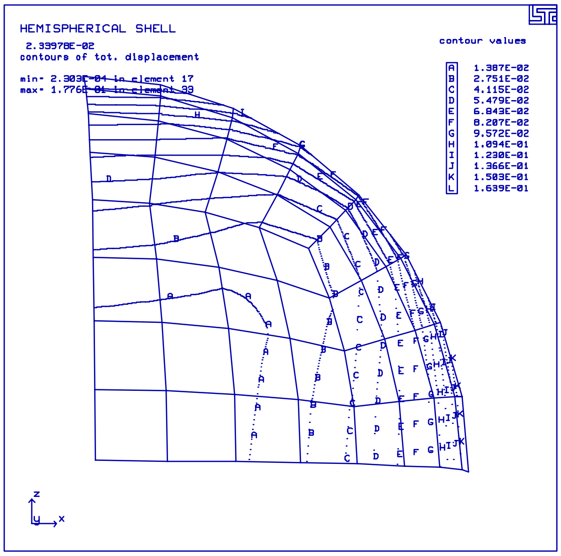
```
*KEYWORD
*TITLE
Twisted Beam
$
$  LSTC Example
$
$  Last Modified: September 15, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     0.018
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         0         0         0         0                   2      1000
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                            -2                   1
$
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                             4
$   cmpflg    ieverp    beamip

$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
     0.001
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    0.0001
$
*DATABASE_BNDOUT
$       dt
    0.0001
$
*DATABASE_GLSTAT
$       dt
    0.0001
$
*DATABASE_NODOUT
$       dt
    0.0001
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
        37
```

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Load node 37, 38, 39 with 0.1667 lbs in both x and y direction.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
        37         1         1 1.667E-01
        38         1         1 1.667E-01
        39         1         1 1.667E-01
        37         2         1 1.667E-01
        38         2         1 1.667E-01
        39         2         1 1.667E-01
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$                   a                   o
           0.000E+00           1.000E+00
           1.000E+03           1.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Twisted Beam
         1         1         1
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         1   2.00e-4  29.00e+6     0.330
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         0                   4                   0
$       t1        t2        t3        t4      nloc
     0.320     0.320     0.320     0.320
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes 1, 2, 3 have fixed boundary conditions.
$
*NODE
$   node               x               y               z      tc      rc
       1   -5.500000E-01    0.000000E+00    0.000000E+00       7       7
       2    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       3    5.500000E-01    0.000000E+00    0.000000E+00       7       7
```

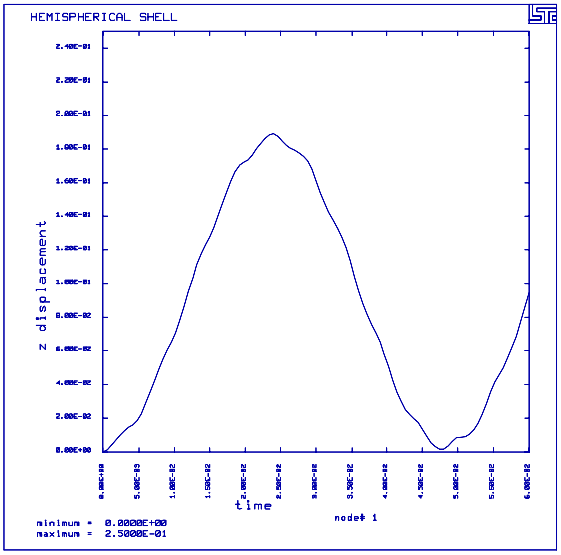
```
       .
       ...  in total, 39 nodes defined
       .
      37    0.000000E+00   -5.500000E-01    1.200000E+01       0       0
      38    0.000000E+00    0.000000E+00    1.200000E+01       0       0
      39    0.000000E+00    5.500000E-01    1.200000E+01       0       0
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       4       5       2
       2       1       2       5       6       3
       .
       ...  in total, 24 shells defined
       .
      23       1      34      37      38      35
      24       1      35      38      39      36
$
*END
```

Results:

```
taurus g=d3plot
19
rx -90 angle 5 mono numc s 40 contour 20
```



```
phs2
nodes 2 1 10 gather
oset 0 0.25 black ntime 3 1 1
```



LS-DYNA Manual Section: *CONTROL_SHELL

Example: Twisted Cantilever Beam

Filename: control_shell.beam-twist.k

Description:

A beam twisted 90 degrees about its length is constrained on one edge and has a point load prescribed normal to the opposite end of the beam.

Model:

The beam measures 12.00 × 1.10 × 0.32 cubic inches. A concentrated load is applied to one node on the end in the x-direction and the other node on the end in the z-direction.

Input:

This model uses the Hughes-Liu five through the thickness integration points (*CONTROL_SHELL, *SECTION_SHELL). The element has the shell normal update calculation performed at each nodal fiber every cycle (*CONTROL_SHELL). Note: This is another example that will not work correctly with the B-T shell formulation (unless warping stiffness is added).

Results:

The beam oscillates about a neutral amplitude.

Reference:

Belytschko, Wang and Chiang.

List of LS-DYNA input deck:

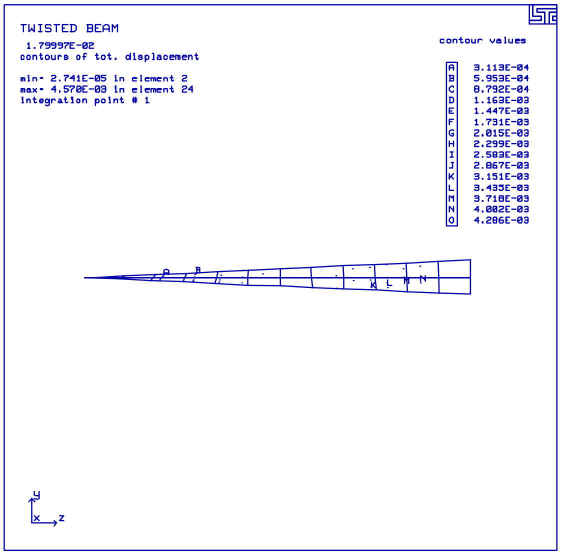
```
*KEYWORD
*TITLE
Hemispherical Shell
$
$  LSTC Example
$
$  Last Modified: September 12, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 6.000E-02
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                            -2                   1
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 6.000E-04
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Load node  1 in the positive x-direction.
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
         1         3         1       1.0
$
$$$$  Load node 46 in the negative z-direction.
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
        46         1         1      -1.0
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
```

```
         1
$          abscissa            ordinate
           0.000E+00           1.000E+00
           1.000E+00           1.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Hemisphere
         1         1         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1 1.000E-03 6.825E+07       0.3 600000.00 0.000E+00 0.000E+00
$      src       srp        fs
 0.000E+00 0.000E+00 0.000E+00
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1                             5
$       t1        t2        t3        t4      nloc
 4.000E-02 4.000E-02 4.000E-02 4.000E-02
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Multiple nodes have boundary conditions to simulate symmetry.
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    1.000000E+01       1       5
       2    1.950897E+00    0.000000E+00    9.807854E+00       0       0
       3    3.826834E+00    0.000000E+00    9.238795E+00       0       0
       .
       ...  in total, 61 nodes defined
       .
      59    8.180990E+00    1.705178E+00    5.492155E+00       0       0
      60    7.794079E+00    3.370117E+00    5.281538E+00       0       0
      61    7.167934E+00    4.930554E+00    4.930554E+00       0       0
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       6       7       2
       2       1       2       7       8       3
       3       1       3       8       9       4
       .
       ...  in total, 48 shells defined
```

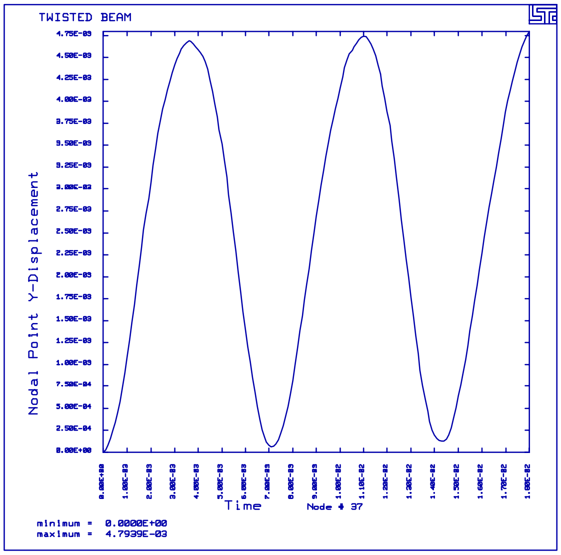
```
            .
           46        1       59       10       15       60
           47        1       60       15       20       61
           48        1       61       20       25       45
$
*END
```

Results:

```
taurus g=d3plot
19
ry 90 state 19 mono numc 15 contour 20
```



```
phs3
nodout
black y-disp
```



LS-DYNA Manual Section: *CONTROL_TIMESTEP

Example: Billet Upset

Filename: control_timestep.billet-forge.k

Description:

A rod of steel is forged between two dies. The billet upset problem is a measure of friction under forming conditions.

Model:

The billet material is isotropic elastic-plastic, and the model has 1• 8 symmetry. The billet measures 2.25 inches in height and 1.26 inches in radius. The die compresses the billet 1.60 inches. The relationship between the shear friction and the normal pressure is bilinear.

Input:

The mass scaling time step size is set to 12 microseconds (*CONTROL_TIMESTEP). The billet nodes contact the die surfaces (*CONTACT_NODES_TO_SURFACE). The Coulomb frictional constant is 0.10 and the constant shear is 2,055 psi . A half sine wave defines the velocity of the die (*BOUNDARY_PRESCRIBED_MOTION).

Results:

The results show that effective plastic strains with and without timestep control are the same. CPU savings is approximately 33% on the cray J90 using 1 cpu..

Reference:

Avitzur, B., Lee, C. H. and Altan, T.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
BILLET UPSET
$
$  LSTC Example
$
$  Last Modified: September 16, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
    0.0015
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                                        -1.200E-07
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
    0.0001
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
   0.00001
$
*DATABASE_MATSUM
$       dt
   0.00001
$
*DATABASE_RBDOUT
$       dt
   0.00001
$
*DATABASE_RCFORC
```

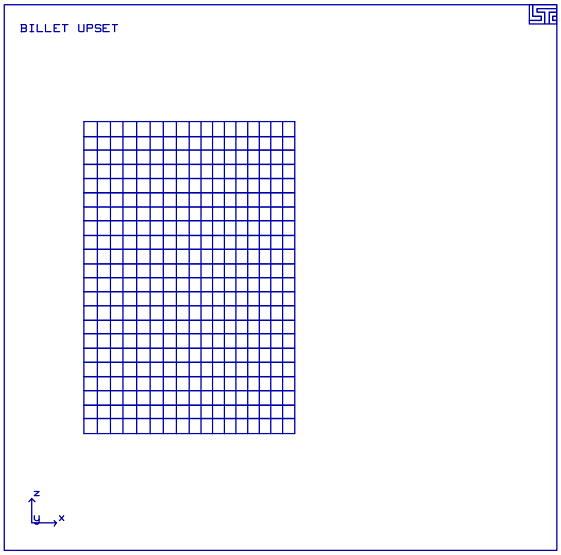
```
$       dt
   0.00001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading - PRESCRIBED_MOTION_RIGID
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      mid       dof       vad      lcid        sf       vid
         2         3         0         1 1.000E+00
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
           0.000E+00           0.000E+00
           5.000E-05          -4.931E+00
           1.000E-04          -1.960E+01
           1.500E-04          -4.365E+01
           2.000E-04          -7.649E+01
           2.500E-04          -1.173E+02
           3.000E-04          -1.651E+02
           3.500E-04          -2.187E+02
           4.000E-04          -2.767E+02
           4.500E-04          -3.378E+02
           5.000E-04          -4.005E+02
           5.500E-04          -4.632E+02
           6.000E-04          -5.243E+02
           6.500E-04          -5.823E+02
           7.000E-04          -6.359E+02
           7.500E-04          -6.837E+02
           8.000E-04          -7.245E+02
           8.500E-04          -7.573E+02
           9.000E-04          -7.814E+02
           9.500E-04          -7.961E+02
           1.000E-03          -8.010E+02
           1.050E-03          -7.961E+02
           1.100E-03          -7.814E+02
           1.150E-03          -7.573E+02
           1.200E-03          -7.245E+02
           1.250E-03          -6.837E+02
           1.300E-03          -6.359E+02
           1.350E-03          -5.823E+02
           1.400E-03          -5.243E+02
           1.450E-03          -4.632E+02
           1.500E-03          -4.005E+02
           1.550E-03          -3.378E+02
           1.600E-03          -2.767E+02
           1.650E-03          -2.187E+02
           1.700E-03          -1.651E+02
           1.750E-03          -1.173E+02
           1.800E-03          -7.649E+01
           1.850E-03          -4.365E+01
           1.900E-03          -1.960E+01
           1.950E-03          -4.931E+00
           2.000E-03           0.000E+00
           2.200E-03           0.000E+00
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_NODES_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2         3         3
$       fs        fd        dc        vc       vdc    penchk        bt        dt
       0.1       0.1           2.055E+03
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$ Part    1    solid: Billet - Aluminum
$
$$$ Part    2    shell: Press - Aluminum - rigid
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Billet - Aluminum
         1         1         1
Press - Aluminum
         2         2         2
$
$$$$  materials
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1   2.50e-4  10.00e+6      0.33
$        c         p      lcss      lcsr

$
$     eps1      eps2      eps3      eps4      eps5      eps6      eps7      eps8
 0.000E+00 5.000E-03 1.000E-02 5.000E-02 1.000E-01 2.000E-01 7.000E-01 4.000E+00
$
$      es1       es2       es3       es4       es5       es6       es7       es8
 4.785E+03 6.505E+03 7.423E+03 1.063E+04 1.254E+04 1.482E+04 2.010E+04 3.081E+04
$
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2   2.50e-4  10.00e+6      0.33
$      cmo      con1      con2
      -1.0       0.0    110111
$   lco/a1        a2        a3        v1        v2        v3
       0.0
$
$$$$  sections
$
*SECTION_SOLID
$      sid    elform
         1         0
$
```

```
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2
$       t1        t2        t3        t4      nloc
 1.000E-02 1.000E-02 1.000E-02 1.000E-02
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Many nodes have boundary conditions in order to simulate symmetry.
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       2    4.687500E-02    0.000000E+00    0.000000E+00       5       7
       3    9.375000E-02    0.000000E+00    0.000000E+00       5       7
       .
       ...  in total, 5755 nodes defined
       .
    5753    9.731613E-01    8.317921E-01    1.126000E+00       0       0

    5754    1.018930E+00    8.704337E-01    1.126000E+00       0       0
    5755    1.064698E+00    9.090752E-01    1.126000E+00       0       0
$
$$$$$  Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       1       2      11      10      82      83      92      91
       2       1       2       3      12      11      83      84      93      92
       3       1       3       4      13      12      84      85      94      93
       .
       ...  in total, 4576 solids defined
       .
    4574       1    5307    5308    3627    3618    5379    5380    3708    3699
    4575       1    5308    5309    3636    3627    5380    5381    3717    3708
    4576       1    5309    5310    3645    3636    5381    5382    3726    3717
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       2    5383    5394    5395    5384
       2       2    5384    5395    5396    5385
       3       2    5385    5396    5397    5386
       .
       ...  in total, 340 shells defined
       .
     338       2    5752    5602    5613    5753
     339       2    5753    5613    5624    5754
     340       2    5754    5624    5635    5755
$
*END
```

Results:

taurus g=d3plot
19
rx -90 angle 5 m 1 view



state 16
numc 15 mono
contour 7

LS-DYNA Manual Section: *CONTROL_ADAPTIVE

Additional Sections:

*DAMPING_GLOBAL
*LOAD_RIGID_BODY

Example: Deep Drawing with Adaptivity

Filename: control_adaptive.cup-draw.k

Description:

This problem includes three tools a punch, a binder and a die and also includes a blank to be formed. The blank is deep drawn by the punch while the binder and die hold the blank edges and help prevent wrinkling. During the process, adaptivity is employed to refine the mesh of the blank to improve accuracy.

Model:

Only 1/4 of the system is modeled because of symmetry. The binder pushes down on the blank against the die using a *LOAD_RIGID command to model the boundary edge condition. The punch is moved down onto the blank with a *BOUNDARY_PRESCRIBED_MOTION_RIGID command. Global damping and contact damping are defined to prevent local nodal vibrations. The time step size is controlled with mass scaling because inertial effects are insignificant in this problem. One way surface to surface contact is defined between the major parts. This allows the drawing (i.e., contact) forces to be monitored using the rcforc ascii output file.

Results:

During the drawing operation, the mesh is refined considerably.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
deep drawing  - blankholder contact damping , mesh refinement
$
$  LSTC Example
$
$  Last Modified: October 14, 1997
$
$  - adaptive meshing
$
$  - the binder pushes down on the blank against the die using a *LOAD_RIGID
$      for the boundary edge condition
$
$  - the punch is moved down onto the blank with a
$     *BOUNDARY_PRESCRIBED_MOTION_RIGID
$
$  - global damping and contact damping
$
$  - time step is controlled with mass scaling
$
$  - there are a lot of constrained nodes defined in *NODE (tc,rc)
$
$
$  Units: gm, cm, micro-s, 1e7N, Mbar, 1e7N-cm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     700.0
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
       .01        0.         2         1
$   usrstr    usrfrc     nsbcs    interm     xpene     ssthk      ecdt   tiedprj

$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
      20.0         1         0         1
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
        0.        0.         0        0.     -0.25         0         0
$
$
```

```
*DATABASE_BINARY_D3PLOT
$       dt       lcdt
      40.0
$
*DATABASE_GLSTAT
$       dt
       1.0
$
*DATABASE_MATSUM
$       dt
       1.0
$
*DATABASE_RBDOUT
$       dt
       5.0
$
*DATABASE_RCFORC
$       dt
       1.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Adaptivity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_ADAPTIVE
$  adpfreq    adptol    adpopt    maxlvl    tbirth    tdeath     lcadp    ioflag
    5.0e+0       0.1         2         2       0.0       0.0         0
$
$
*DAMPING_GLOBAL
$     lcid    valdmp
         3
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         3
$           abscissa            ordinate
           0.000E+00           0.000E+00
           1.000E+04           0.000E+00
           1.001E+04           3.000E+03
           2.000E+04           3.000E+03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading and Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      pid       dof       vad      lcid        sf       vid     death
         1         2         0         1       -1.
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
```

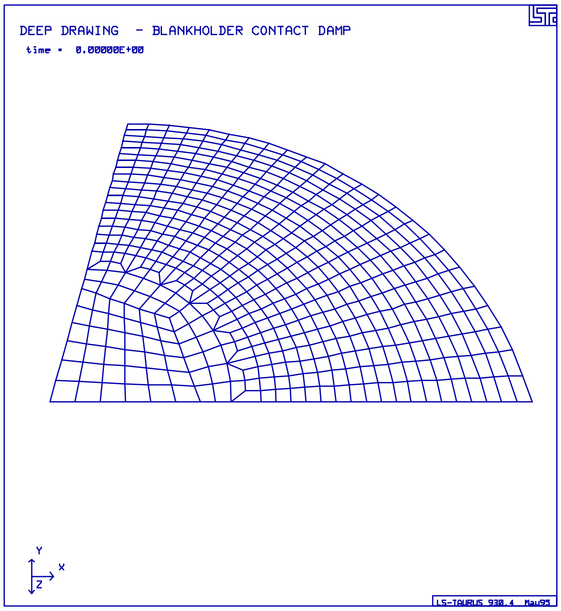
```
          0.000E+00           0.000E+00
          1.000E+02           2.912E-03
          2.000E+02           5.540E-03
          3.000E+02           7.625E-03
          4.000E+02           8.963E-03
          5.000E+02           9.425E-03
          6.000E+02           8.963E-03
          7.000E+02           7.625E-03
          8.000E+02           5.540E-03
          9.000E+02           2.912E-03
          1.000E+03           0.000E+00
$
$  From a sheet metal forming example.  A blank is hit by a punch, a binder is
$  used to hold the blank on its sides.  The rigid holder (part 2) is held
$  against the blank using a load applied to the cg of the holder.
$
$  The direction of the load is in the y-direction (dof=2) but is scaled
$  by sf = -1 so that the load is in the correct direction.  The load
$  is defined by load curve 2.
$
$
*LOAD_RIGID_BODY
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      pid       dof      lcid        sf       cid        m1        m2        m3
         2         2         2      -1.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2
$           abscissa            ordinate
          0.000E+00           8.000E-05
          1.000E+04           8.000E-05
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
punch
         1         1         2         0         0         0         0
binder
         2         1         2         0         0         0         0
blank
         3         1         1         0         0         0         1
die
         4         1         2         0         0         0         0
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1 2.700E+00 0.690E+00 3.000E-01 8.180E-04 0.010E+00 1.000E+00 0.000E+00
$      src       srp        fs
 0.000E+00 0.000E+00
$
$
*MAT_RIGID

$      mid        ro         e        pr         n    couple         m     alias
```

```
        2 8.450E-00 0.690E+00 3.000E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$      cmo      con1      con2
 0.000E+00 0.000E+00
$   lco/a1        a2        a3        v1        v2        v3

$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2        1.        5.        0.        0.         0
$       t1        t2        t3        t4      nloc
      .100      .100      .100      .100
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - sliding interface definitions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$  contact between blank (slaves) and punch (master)
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE

$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         1         2         2         0         0         0         0
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
        .2        .2         0         0       20.         0         0         0
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
         0         0         0         0         0         0         0         0
$
$
$$$$$  contact between blank (slaves) and binder (master)
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
         3         2         2         2         0         0         0         0
        .2        .2         0         0       20.         0         0         0
         0         0         0         0         0         0         0         0
$
$
$$$$$  contact between blank (slaves) and die (master)
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
         3         4         2         2         0         0         0         0
        .2        .2         0         0       20.         0         0         0
         0         0         0         0         0         0         0         0
$
$
*SET_PART
$      sid
         3
$      pid
         3
$
*SET_PART
         1
         1
$
*SET_PART
         2
```

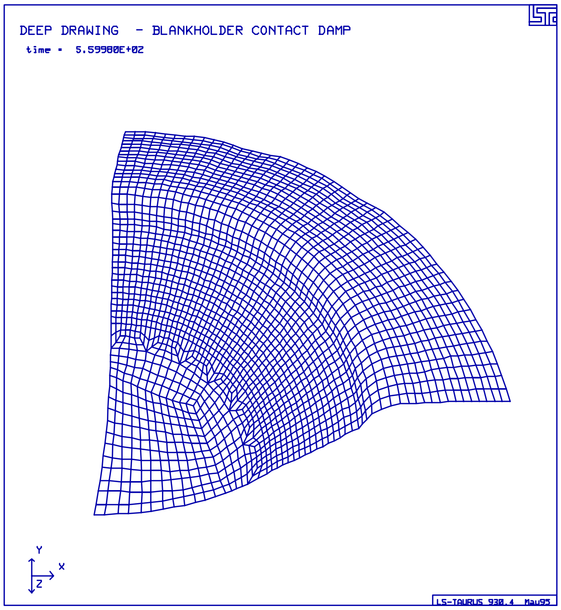
```
         2
$
*SET_PART
         4
         4
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
       1 0.000000000E+00 0.505000019E+01-0.500000000E+01       6       7
       2 0.392295510E+00 0.505000019E+01-0.498458672E+01       6       7
       .
       ...  in total, 1799 nodes defined
       .
    1798 0.523225009E+00-0.100000001E+00-0.798287010E+01       7       7
    1799-0.349690993E-06-0.100000001E+00-0.800000000E+01       7       7
$
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1      12      13       2
       2       1       2      13      14       3
       .

       ...  in total, 1644 shells defined
       .
    1643       4    1772    1797    1798    1773
    1644       4    1773    1798    1799    1774
$
*END
```

Results:

```
taurus g=d3plot
rx 45 m 3 s 15 center
state 1 view
```



```
state 15
view
```



LS-DYNA Manual Section: *CONTROL_ADAPTIVE

Additional Sections:

*CONTROL_SUBCYCLE

Example: Square Crush Tube with Adaptivity

Filename: control_adaptive.square-beam.k

Description:

A square cross section of a crush tube uses adaptivity to re-fine the mesh as needed to improve accuracy..

Model:

Only 1/4 of the tube is modeled because of symmetry. The nodes on top of the crush tube are assigned extra mass with *ELEMENT_MASS and given an initial velocity in the y-direction of -5,646 mm/s. The nodes on the bottom of the tube are fixed in y-translation. Automatic single surface contact is defined to prevent penetration when the folds of the crush tube start to form. The model has subcycling defined.

Results:

The mesh at the fold location in the crush tube is automatically re-fined as the crush progresses.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
square cross section for single surface contact and adaptivity test
$
$  LSTC Example
$
$  Last Modified: October 15, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 3.000E-03
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt       lcdt
  0.999e-4
$
*DATABASE_GLSTAT
$       dt
   0.00002
$
*DATABASE_MATSUM
$       dt
   0.00002
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Adaptivity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_ADAPTIVE
$  adpfreq    adptol    adpopt    maxlvl    tbirth    tdeath     lcadp    ioflag
    1.0e-4       5.0         2         2       0.0       0.0         0
$
$
*CONTROL_SUBCYCLE
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

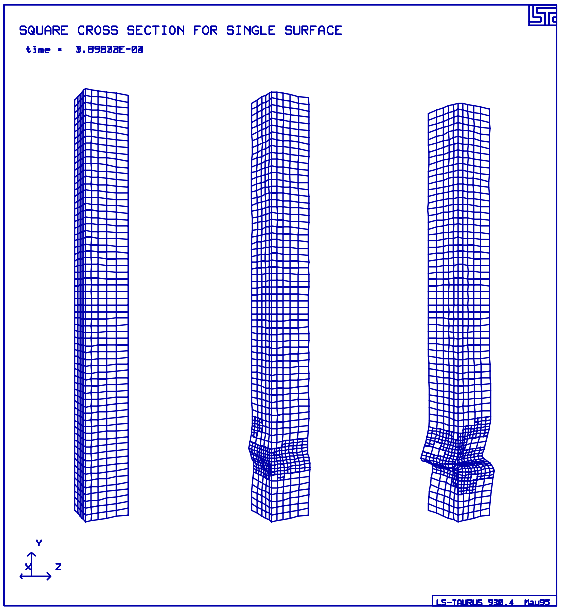
```
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INITIAL_VELOCITY_NODE
$      nid        vx        vy        vz       vxr       vyr       vzr

        650.0000E+00-0.5646E+40.0000E+00
        660.0000E+00-0.5646E+40.0000E+00
        990.0000E+00-0.5646E+40.0000E+00
       1320.0000E+00-0.5646E+40.0000E+00
       1650.0000E+00-0.5646E+40.0000E+00
       1980.0000E+00-0.5646E+40.0000E+00
       4230.0000E+00-0.5646E+40.0000E+00
       4560.0000E+00-0.5646E+40.0000E+00
       4890.0000E+00-0.5646E+40.0000E+00
       5220.0000E+00-0.5646E+40.0000E+00
       5550.0000E+00-0.5646E+40.0000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constraints
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONSTRAINED_NODE_SET
$     nsid       dof
        11         2
$
*SET_NODE
$      sid       da1
        11        11
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
        65        66        99       132       165       198       423       456
       489       522       555
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - sliding interface definitions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_AUTOMATIC_SINGLE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         0         2         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$
*SET_PART
$      sid       da1
         1         1
$      pid
         1
```

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
square-tube
         1         1         1         0         0         0         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta

         1 7.850E-09 1.994E+05 3.000E-01 3.366E+02 1.000E+00 1.000E+00 0.000E+00
$      src       srp        fs

$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2        1.        3.        0.        0.         0
$       t1        t2        t3        t4      nloc
       1.2       1.2       1.2       1.2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
       1-3.501449966E+01 0.000000000E+00-3.501800156E+01       0       0
       2-3.003639984E+01 0.000000000E+00-3.496210098E+01       0       0
       .
       ...  in total, 715 nodes defined
       .
     714-3.504100037E+01-1.550000000E+02-4.540000111E-02       3       4
     715-3.497240067E+01-1.600000000E+02 1.499999966E-02       7       7
$
$$$$$  Elements - Shells
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2       4       3
       2       1       3       4       6       5
       .
       ...  in total, 640 shells defined
       .
     639       1     681     682     714     713
     640       1     682     683     715     714
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$  Elements - Discrete Masses
```

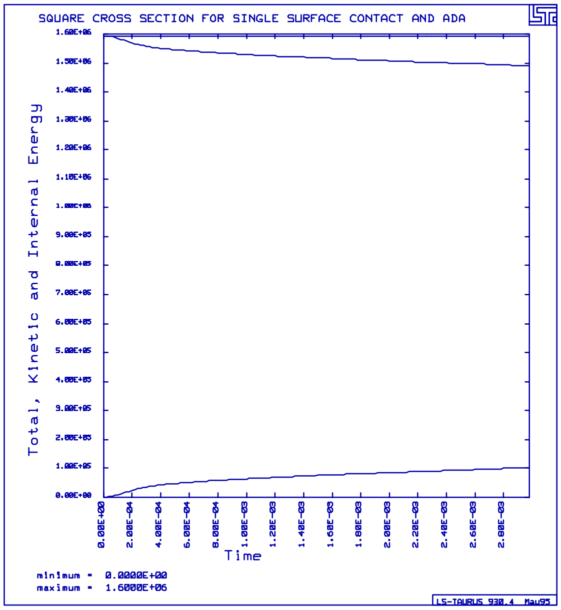
```
$
*ELEMENT_MASS
$    eid     nid            mass
      65      65       1.000E-02
      66      66       1.000E-02
      99      99       1.000E-02
     132     132       1.000E-02
     165     165       1.000E-02
     198     198       5.000E-03
     423     423       1.000E-02
     456     456       1.000E-02
     489     489       1.000E-02
     522     522       1.000E-02
     555     555       5.000E-03
$
*END
```

Results:

```
taurus g=d3plot
ry 120 xtran -150 v xtran 150 s 5 over v
xtran 150 s 20 over v
```



```
phs3 glstat
otxt Total, Kinetic and Internal Energy
oset 0 1.6e6 total over kine over inte
```



LS-DYNA Manual Section: *CONTROL_ADAPTIVE

Additional Sections:

*DEFINE_COORDINATE_VECTOR

Example: Cylinder Undergoing Deformation with Adaptivity

Filename: control_adaptive.cylinder.k

Description:

Several nodes on a cylinder are given initial velocities towards the center of the cylinder causing the cylinder to indent. To improve accuracy, adaptivity is defined so that the mesh of the cylinder is re-fined during the deformation.

Model:

Only 1/4 of the system is modeled because of symmetry. The boundary conditions on the cylinder are defined with single point constraints (SPC's). Because of the geometry orientation, several of the SPC's require local coordinate system defined using the keyword *DEFINE_COORDINATE_VECTOR.

Results:

Before and after mesh refinement are shown in the figures. Additionally, the total, kinetic and internal energy from the glstat ascii file are shown. The entire initial kinetic energy is absorbed by the cylinder due to material deformation (internal energy).

List of LS-DYNA input deck:

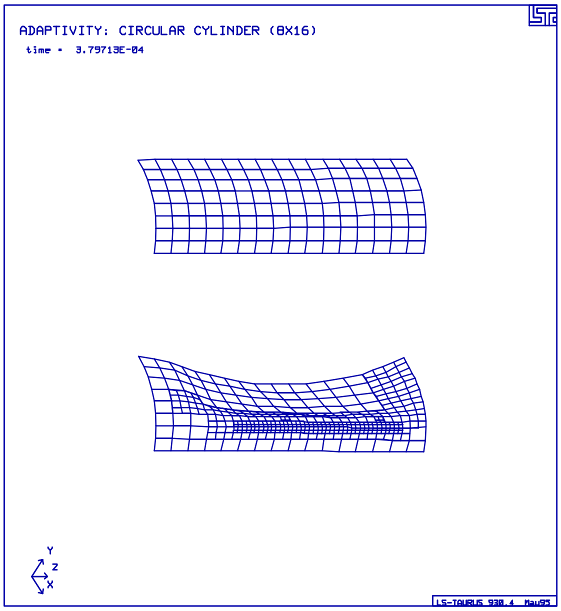
```
*KEYWORD
*TITLE
ADAPTIVITY: circular cylinder (8x16)
$
$  LSTC Example
$
$  Last Modified: October 14, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
    0.0004
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                         1         2         1
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
   0.00002
$
*DATABASE_GLSTAT
$       dt
   0.00002
$
*DATABASE_MATSUM
$       dt
   0.00002
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Adaptivity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_ADAPTIVE
$  adpfreq    adptol    adpopt    maxlvl    tbirth    tdeath     lcadp    ioflag
   1.01e-5      10.0         2         3       0.0       0.0         0         1
$
$
```

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
al6061-t6
         1         1         1         0         0         0         1
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1 2.500E-04 1.050E+07 3.300E-01 4.400E+04 0.000E+00 1.000E+00
$
$      src       srp        fs
 0.000E+00 0.000E+00
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2        1.        5.        0.        0.         0
$       t1        t2        t3        t4      nloc
     0.125     0.125     0.125     0.125
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_SPC
$      nid       cid      dofx      dofy      dofz     dofrx     dofry     dofrz
         1         1         1         1         0         0         1         1
        18         2         0         1         0         0         1         1
        35         3         0         1         0         0         1         1
       .
       ...  in total, 48 SPC's defined
       .
        68         4         1         1         0         0         1         1
        85         5         1         1         0         0         1         1
       102         6         1         1         0         0         1         1
       119         7         1         1         0         0         1         1
       120         8         0         1         0         0         1         1
       153         1         1         1         1         1         1         1
$
$
*DEFINE_COORDINATE_VECTOR
$      cid        xx        yx        zx        xv        yv        zv
         1        1.        0.        0.        0.        1.        0.
         2   0.99144  -0.13053   0.00000   0.13053   0.99144   0.00000
         3   0.96593  -0.25882   0.00000   0.25882   0.96593   0.00000
         4   0.92388  -0.38268   0.00000   0.38268   0.92388   0.00000
         5   0.86603  -0.50000   0.00000   0.50000   0.86603   0.00000
         6   0.79335  -0.60876   0.00000   0.60876   0.79335   0.00000
         7   0.70711  -0.70711   0.00000   0.70711   0.70711   0.00000
         8   0.60876  -0.79335   0.00000   0.79335   0.60876   0.00000
         9   0.50000  -0.86603   0.00000   0.86603   0.50000   0.00000
```

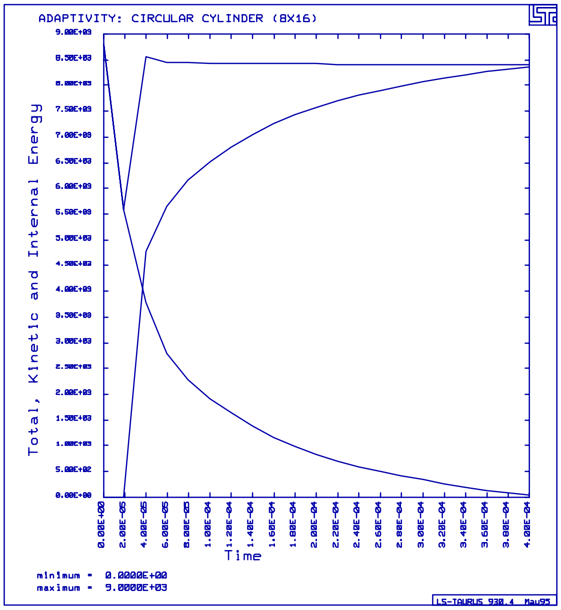
```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INITIAL_VELOCITY_NODE
$      nid        vx        vy        vz       vxr       vyr       vzr
         2      0.00  -5650.00      0.00      0.00      0.00      0.00
        19   -737.47  -5601.66      0.00      0.00      0.00      0.00
       .
       ...  in total, 65 initial nodal velocities defined

       .
        48  -1462.33  -5457.48      0.00      0.00      0.00      0.00
        53  -2162.16  -5219.92      0.00      0.00      0.00      0.00
        82  -2825.00  -4893.04      0.00      0.00      0.00      0.00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
       1 0.000000000E+00 0.294000006E+01 0.000000000E+00       0       0
       2 0.000000000E+00 0.294000006E+01-0.785000026E+00       0       0
       .
       ...  in total, 153 nodes defined
       .
     152 0.254611492E+01 0.147000003E+01-0.117749996E+02       0       0
     153 0.254611492E+01 0.147000003E+01-0.125600004E+02       0       0
$
$$$$$$$$$$$   Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1      18      19       2
       2       1       2      19      20       3
       .
       ...  in total, 128 shells defined
       .
     127       1     134     151     152     135
     128       1     135     152     153     136
*END
```

Results:

```
taurus g=d3plot
angle 1 ry 90 rx -45 ry -45 ytrans 3 view
ytrans -6 s 20 over view
```



```
phs3 glstat
otxt Total, Kinetic and Internal Energy
oset 0 9e3 total over kine over inte
```



LS-DYNA Manual Section: *DAMPING_GLOBAL

Additional Sections:

*CONTROL_DAMPING
*LOAD_BODY_Z

Example: Tire Bounces on the Ground and Damps Out

Filename: damping.tire.k

Description:

A simple model of a tire is placed under gravity loading and drops onto rigid solid elements. Fully integrated shell elements are used for the tire to prevent hourglassing from damping out the model. Additionally, rigid solid elements are used for modeling the ground instead of a rigidwall because the rigidwall will also damp the system because of its' perfectly plastic contact definition. Thus, to damp out the bouncing, global damping is applied to the system.

Model:

Global damping of 0.5 is applied to the system using the *DAMPING_GLOBAL keyword. Contact between the tire and ground is defined using node to surface contact. Gravity is applied with the *LOAD_BODY_Z command.

Results:

The total energy of the system comes from the external energy of gravity (potential energy of "mgh"). This energy is absorbed by the damping in the model.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
A simple tire bouncing on the ground with damping.
$
$  LSTC Example
$
$  Last Modified: October 13, 1997
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
     40.01
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*DATABASE_BINARY_D3PLOT
$       dt       lcdt
      10.0
$
*DATABASE_BINARY_D3THDT
$       dt       lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
       0.1
$
*DATABASE_MATSUM
$       dt
       0.1
$
*DATABASE_NODOUT
$       dt
       0.1
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
      8914      8746      8918
$
*DATABASE_RCFORC
$       dt
       0.1
$
*DATABASE_RWFORC
$       dt
```

```
       0.1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Damping
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DAMPING_GLOBAL
$     lcid    valdmp
         0       0.5
$
*CONTROL_DAMPING
$   nrcyck     drtol    drfctr    drterm    tssfdr    irelal     edttl    idrflg
       100    1.0e-3     0.995               0.9
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Gravity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_BODY_Z
$     lcid        df    lciddr        xc        yc        zc
         1 9.810E-03
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$          abscissa            ordinate
              0.00               1.000
           1000.00               1.000
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - sliding interface definitions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Prevent the nodes of the tire from penetrating the ground.
$
*CONTACT_NODES_TO_SURFACE
$
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
        36        76         3         3
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
```

*DAMPING_GLOBAL

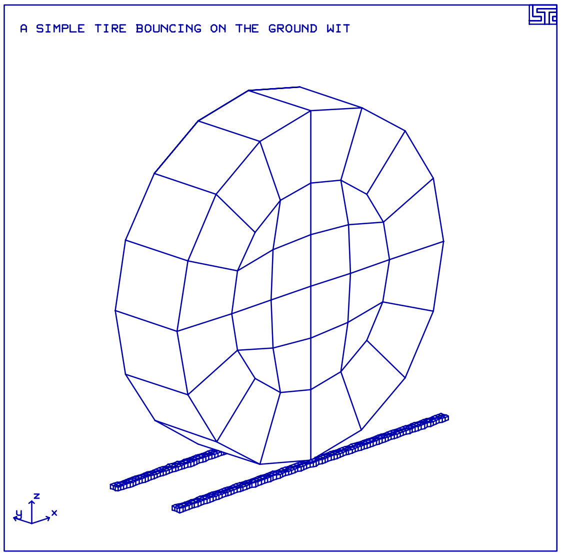
Tire Bounces on the Ground and Damps Out

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
wheel
        35         1         1
tire
        36         1         1
ground
        76        76         2
$
$$$$  Materials

$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 0.783E-05     200.0       0.3     0.207               0.750
$  Cowper/Symonds Strain Rate Parameters
$        C         p      lcss      lcsr
        40         5
$  Plastic stress/strain curves
     0.000     0.080     0.160     0.400     1.000
     0.207     0.250     0.275     0.290     0.300
$
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2 0.783E-05     200.0       0.3
$
$      cmo      con1      con2
       1.0         7         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         6             3.0000
$       t1        t2        t3        t4      nloc
      1.00      1.00      1.00      1.00
$
$
*SECTION_SOLID
        76         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc

    8719 -1.16673000E+02 -6.24000000E+02 -1.16673000E+02
    8720 -1.52440000E+02 -6.24000000E+02 -6.31430000E+01
```

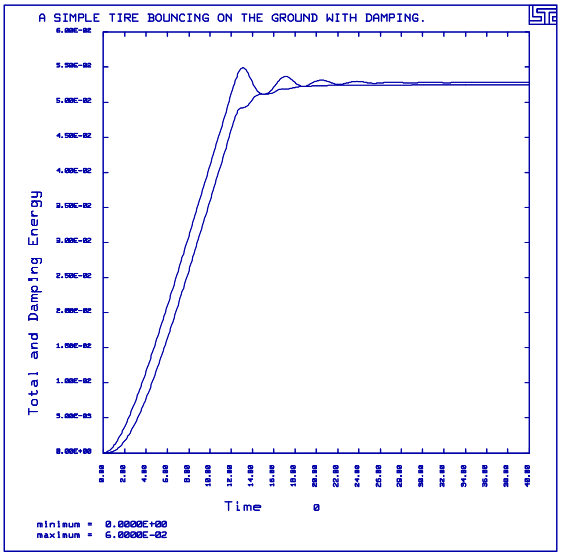
```
       .
       ...  in total, 1522 nodes defined
       .
   52040 2.444749625E+02 -7.51864725E+02 -2.79200000E+02
   52049 2.698749875E+02 -7.51864725E+02 -2.79200000E+02
$
$$$$$$$$$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
    8710      35    8719    8722    8723    8720
       .
       ...  in total, 96 shells defined
       .
    8949      36    8929    8932    8926    8924
$
$$$$$$$$$$$$$  Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
   50880      76   50315   52520   52902   52521   52362   52686   52950   52687
       .
       ...  in total, 534 solids defined
       .
   51588      76   53833   53962   53834   53423   53424   53835   53425   53689
$
$$$$$$$  Nodal Mass Elements
$
*ELEMENT_MASS
$    eid     nid      mass
    8730    8730      10.0
    8746    8746      10.0
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90
ry 45 rx 20 view
```



```
phs3 glstat
otxt Total and Damping Energy
oset 0 0.06 total over damping
```



LS-DYNA Manual Section: *DEFORMABLE_TO_RIGID

Additional Sections:

*BOUNDARY_SPC_NODE
*LOAD_BODY_Y
*RIGID_DEFORMABLE_R2D

Example: Interaction of Pendulums

Filenames: deformable_to_rigid.pendulum.k
deformable_to_rigid.pendulum.res

Execution lines:

```
ls940  i= deformable_to_rigid.pendulum.k
ls940  i= deformable_to_rigid.pendulum.res r=d3dump01
```

Description:

Two spheres are connected to wires to form two pendulums. One sphere is in a horizontal position with gravitational acceleration, base acceleration and is given an initial velocity in the vertical direction. The other sphere is in the vertical direction. The spheres are treated as rigid bodies while no contact or deformation occurs (i.e., when the horizontal pendulum swings down towards the vertical pendulum). The spheres are switched to deformable through a restart file so that they become flexible during contact.

Model:

Both spheres are modeled using shell elements. The pendulum wires are modeled using elastic beams. Automatic single surface contact is used during the impact phase.

Reference:

Reid, J.D.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Pendulum with 2 spheres colliding
$
$  LSTC Example
$
$  - uses *DEFORMABLE_TO_RIGID option to decrease execution time before impact
$
$  - one sphere is given an initial velocity (gravity alone just takes
$      too long for the pendulum to swing)
$
$
$  Last Modified: September 16, 1997
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
      11.0         0       0.0       0.0       0.0
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlchk    penopt    thkchg     orien
                                       2
$   usrstr    usrfrc     nsbcs    interm     xpene

$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
                                       1         2
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
      1.00
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
```

```
$
$
*DATABASE_GLSTAT
$       dt
      0.10
$
*DATABASE_MATSUM
$       dt

      0.10
$
*DATABASE_NODOUT
$       dt
      0.10
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3
       350       374       678       713
$
*DATABASE_RBDOUT
$       dt
      0.10
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp
         0
$  Equating ssid to zero means that all segments are included
$
$       fs        fd
      0.08      0.08

$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Gravity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*LOAD_BODY_Y
$     lcid        sf    lciddr        xc        yc        zc
         1   0.00981
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$          abscissa            ordinate
$
               0.00               1.000
           10000.00               1.000
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$$$$  Boundary and Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Constrain translation of end points of beams
$
*BOUNDARY_SPC_NODE
$      nid       cid      dofx      dofy      dofz     dofrx     dofry     dofrz
     45004         0         1         1         1         0         0         0
     45005         0         1         1         1         0         0         0
     45010         0         1         1         1         0         0         0
     45011         0         1         1         1         0         0         0
$
$
$$$$  The nodes within box 5 are given an initial velocity.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
                             5
$
$       vx        vy        vz        wx        wy        wz
       0.0     -12.0       0.0
$
*DEFINE_BOX
$    boxid       xmm       xmx       ymn       ymx       zmn       zmx
         5    -120.0     -80.0      80.0     120.0     -30.0      30.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$   SPHERES
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
sphere1
         1         1         1
sphere2
         2         2         1
$
$
$$$$ Materials
$
$  Aluminum
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1   2.70e-6      68.9     0.330     0.286   0.00689
$      src       srp        fs

$
$$$$ Sections
$
$
*SECTION_SHELL
```

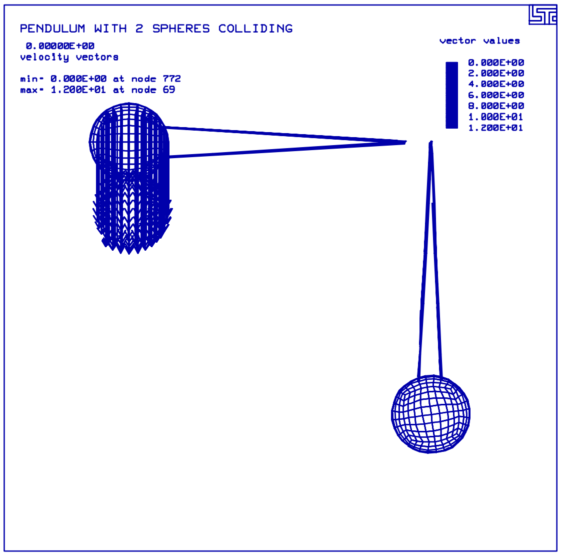
```
$
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0
$
*SECTION_SHELL
$
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         2
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0
$
$
$$$$$   PENDULUM WIRES - ELASTIC BEAMS
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Pendulum Wires - Elastic Beams
        45        45        45
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k

        45   7.86e-6     210.0      0.30
$
$
*SECTION_BEAM
$      sid    elform      shrf   qr/irid       cst
        45         3   1.00000       1.0
$ res:   a       iss       itt       irr        sa
      10.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Deformable Switching
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DEFORMABLE_TO_RIGID
$      pid       mrb
         1
$
*DEFORMABLE_TO_RIGID
$      pid       mrb
         2
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1 -1.08660250E+02 9.133975000E+01 -3.66025000E+00
```

```
       2 -1.09496480E+02 9.331914000E+01 -4.49648000E+00
       3 -1.10108300E+02 9.545641000E+01 -5.10830000E+00
       .
       ...  in total, 784 nodes defined
       .
     770 2.654228546E+01 -6.85637234E-01 1.355349000E+01
     771 2.563811870E+01 1.747789010E+00 1.314240000E+01
     772 2.445826961E+01 3.903858475E+00 1.250087000E+01
   45004 5.000000000E+00 1.000000000E+02 -5.00000000E+01
   45005 5.000000000E+00 1.000000000E+02 6.000000000E+01
   45010 1.500000000E+01 1.000000000E+02 -5.00000000E+01
   45011 1.500000000E+01 1.000000000E+02 6.000000000E+01
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$    Extra Nodes for Beams
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
   45012 -8.83925000E+01 1.057467600E+02 -7.46760000E-01
   45013 9.444594624E+00 8.495260182E+00 -1.11255000E+00
   45014 -8.80996038E+01 9.496034978E+01 -7.46760000E-01
   45015 1.816524677E+01 8.921481149E+00 -7.46760000E-01
   45016 -8.80996068E+01 1.057467600E+02 1.003965322E+01
   45017 9.446435484E+00 8.493592403E+00 1.104210976E+01
   45018 -8.79698503E+01 9.483059027E+01 1.016940973E+01
   45019 1.816697500E+01 8.920056610E+00 1.067986974E+01
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*ELEMENT_BEAM
$    eid     pid      n1      n2      n3
   45000      45     350   45004   45012
   45001      45     678   45010   45013
   45002      45     346   45004   45014
   45003      45     681   45010   45015
   45004      45     378   45005   45016
   45005      45     710   45011   45017
   45006      45     374   45005   45018
   45007      45     713   45011   45019
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1      10      11       2
       2       1       2      11      12       3
       3       1       3      12      13       4
       .
       ...  in total, 768 shells defined
       .
     766       2     770     643     651     771
     767       2     771     651     659     772
     768       2     772     659     667     723
$
*END

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

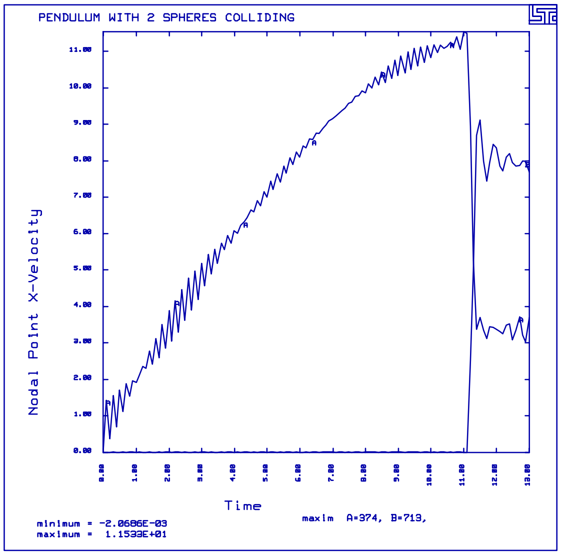
```
*KEYWORD
*TITLE
Pendulum with 2 spheres colliding
$
$
$$$$$   Restart
$
$  Last Modified: September 16, 1997
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Switch spheres to deformables
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*RIGID_DEFORMABLE_R2D
$      pid
         1
$
*RIGID_DEFORMABLE_R2D
$      pid
         2
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   ENDTIM    ENDCYC     DTMIN    ENDENG    ENDMAS
      13.0         0       0.0       0.0       0.0
$
$$$$  Increase d3plot output frequency to capture deformation of impact better.
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
      0.10
$
*END
```

Results:

taurus g=d3plot
19
state 1 angle 1 vect v



phs3
nodout
x-vel 374 713



LS-DYNA Manual Section: *INTEGRATION_SHELL

Additional Sections:

*DAMPING_GLOBAL
*LOAD_NODE_POINT

Example: Cantilever Beam with Lobotto Integration

Filename: integration_shell.lobotto.beam.k

Description:

A cantilever beam has a concentrated load, and then the beam vibration critically damps. Lobotto integration rules place the quadrature points on the true surfaces of the shell. [See Hughes].

Model:

The plate measures 1.00 × 0.10 × 0.01 in^3 and is modeled with 60 Belytschko-Tsay shell elements. The displacement of the nodes is fixed at one end and a concentrated load is applied to the other end. Symmetry conditions for the plane strain case exist on the beam sides.

Input:

The concentrated loads and load curve definition 1 defines the load on the end of the beam (*LOAD_NODE_POINT, *DEFINE_CURVE). The beam is critically damped (*DAMPING_GLOBAL) The number of integration points is 5 (*SECTION_SHELL). The shell integration rule is the Lobotto integration rule (*SECTION_SHELL)

Results:

The displacement of the beam damps out critically. The x-stress values at the integration points exhibit tension on one side, compression on the opposite side, and balance at the neutral axis.

*INTEGRATION_SHELL

Cantilever Beam with Lobotto Integration

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Lobotto Integration
$
$  LSTC Example
$
$  Last Modified: September 17, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     0.015
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         0         0         0         0                   2      1000
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
    0.0003
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
       10.
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                             5
$   cmpflg    ieverp    beamip

$
*DATABASE_GLSTAT
$       dt
    0.0001
$
*DATABASE_ELOUT
$       dt
    0.0001
$
*DATABASE_HISTORY_SHELL
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
*DATABASE_NODOUT
$       dt
    0.0001
```

```
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
        31
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Load nodes 31, 62, 93 in the negative z-direction.
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
        31         3         1 -1.00E+00
        62         3         1 -1.00E+00
        93         3         1 -1.00E+00
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$                  a                   o
           0.000E+00           0.000E+00
           8.000E-03           1.667E-03
           1.534E-02           1.667E-03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Damping
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DAMPING_GLOBAL
$     lcid    valdmp
         2       0.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2
$                  a                   o
           0.000E+00           0.000E+00
           8.000E-03           0.000E+00
           1.000E-02           2.353E+03
           1.534E-02           2.353E+03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Cantilever Beam - Aluminum

         1         1         1
```

Cantilever Beam with Lobotto Integration

```
$
$
*MAT_PLASTIC_KINEMATIC
$      mid        ro         e        pr      sigy      etan      beta
         1   7.85e-4  10.00e+6     0.300   20000.0    100000       1.0
$      src       srp        fs
       0.0       0.0       0.0
$
$$$$  irid = -1  ===> integration rule 1 used (see below)
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         0                   5                  -1
$       t1        t2        t3        t4      nloc
     0.010     0.010     0.010     0.010
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Integration Rule
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INTEGRATION_SHELL
$     irid       nip      esop
         1         5
$        s        wf       pid
-1.000E+00 1.000E-01
-6.546E-01 5.444E-01
 0.000E+00 7.111E-01
 6.546E-01 5.444E-01
 1.000E+00 1.000E-01
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       2    3.333334E-02    0.000000E+00    0.000000E+00       2       6
       3    6.666667E-02    0.000000E+00    0.000000E+00       2       6
       .
       ...  in total, 93 nodes defined
       .
      91    9.333333E-01    1.000000E-01    0.000000E+00       2       6
      92    9.666666E-01    1.000000E-01    0.000000E+00       2       6
      93    1.000000E+00    1.000000E-01    0.000000E+00       2       6
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1      32      33       2
       2       1       2      33      34       3
       3       1       3      34      35       4
       .
       ...  in total, 60 shells defined
       .
      58       1      59      90      91      60
```

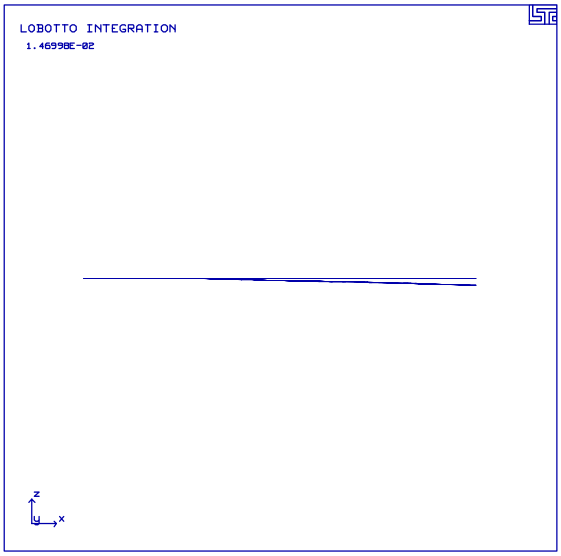
```
      59        1       60       91       92       61
      60        1       61       92       93       62
$
*END
```

*INTEGRATION_SHELL

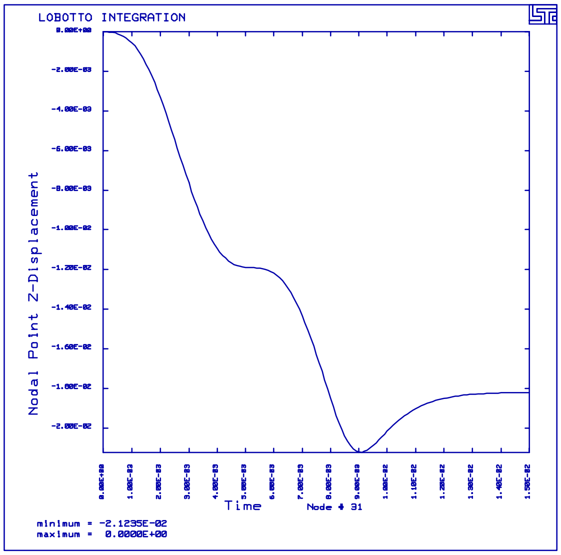
Cantilever Beam with Lobotto Integration

Results:

```
taurus g=d3plot
19
rx -90 s 50 udg 1 g
```



```
phs3
nodout
z-disp
```



LS-DYNA Manual Section: *INTERFACE_COMPONENT

Additonal Sections:

*INITIAL_VELOCITY
*INTERFACE_LINKING_SEGMENT

Example: An Interface File Controls the Response of a Cube

Filenames: interface_component.cube.k
interface_component.cube.rk

Execution Line:

```
LS940 i=interface_component.cube.k z=d3iff
```

After completion, copy d3iff to a separate directory containing interface_component.cube.rk, then from that directory run:

```
LS940 i=interface_component.cube.rk l=d3iff
```

Description:

A cube, one solid element, strikes and rebounds from an elastic plate. In the first run, an interface file (d3iff) is created that contains the position of the bottom segment of the cube. In the second run, the cube mesh refinement increases from 1 element to 8 elements. The interface file is then used to control the position of the bottom of the new cube as if it underwent the same impact as the cube in run one..

Model:

The material of the cube and the plate are elastic. The plate, that measures 40 × 40 × 2 mm^3, is modeled with 16 Belytschko-Tsay shell elements . The cube has a side length of 10 mm and is initially positioned 10 mm above the plate. The cube is given an initial velocity towards the plate.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
INTERFACE SEGMENTS (FIRST ANALYSIS)
$
$  LSTC Example
$
$  Last Modified: September 18, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
    0.0003
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$$$$  opifs - output interval for interface file
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
                                          2.000E-6
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                0.10
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
   0.00002
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
   0.00001
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$   cmpflg    ieverp    beamip

$
*DATABASE_GLSTAT
$       dt
   0.00001
$
*DATABASE_NODOUT
```

```
$       dt
   0.00001
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
       101
$
*DATABASE_RCFORC

$       dt
   0.00001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Interface
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Save the behavior on the following segment in the interface file.
$$$$  This file will then be used in the second analysis.
$
*INTERFACE_COMPONENT_SEGMENT
$      sid
         3
$
*SET_SEGMENT
$      sid       da1       da2       da3       da4
         3
$       n1        n2        n3        n4        a1        a2        a3        a4
       101       102       104       103
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Velocity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  All nodes in box 1 are given an initial velocity (nodes of the cube).
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
                             1
$       vx        vy        vz
       0.0       0.0 -100000.0
$
*DEFINE_BOX
$    boxid       xmm       xmx       ymn       ymx       zmn       zmx
         1      15.0      25.0      15.0      25.0      10.0      20.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Contact - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Contact between the bottom of the cube (segment set 1) and the plate.
```

```
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*SET_SEGMENT
$      sid       da1       da2       da3       da4
         1
$       n1        n2        n3        n4        a1        a2        a3        a4
       101       103       104       102
$
*SET_SEGMENT
$      sid       da1       da2       da3       da4
         2
$       n1        n2        n3        n4        a1        a2        a3        a4
         7         8        13        12
         8         9        14        13
        12        13        18        17
        13        14        19        18
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Plate
         1         1         1
Cube
         2         2         2
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         1   2.00e-8  100000.0     0.300
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         2   1.00e-8  100000.0     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333       2.0       3.0
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
*SECTION_SOLID
$      sid    elform
         2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$

$$$$  Define Nodes and Elements
```

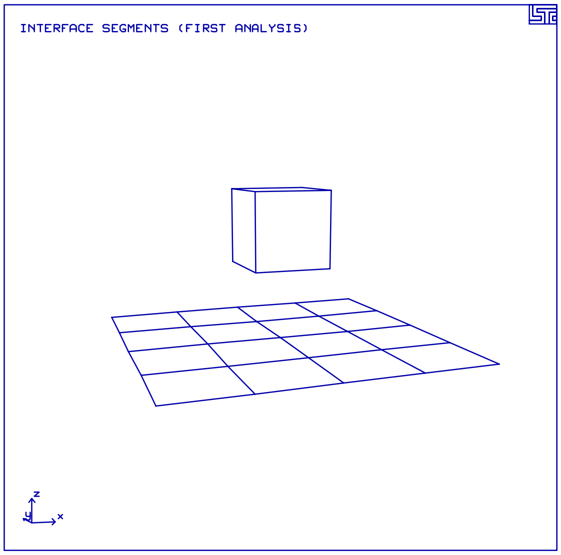
```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       0
       2    1.000000E+01    0.000000E+00    0.000000E+00       7       0
       3    2.000000E+01    0.000000E+00    0.000000E+00       7       0
       .
       ...  in total, 33 nodes defined
       .
     106    2.500000E+01    1.500000E+01    2.000000E+01       0       0
     107    1.500000E+01    2.500000E+01    2.000000E+01       0       0
     108    2.500000E+01    2.500000E+01    2.000000E+01       0       0
$
$$$$$  Solid and Shell Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
     101       2     101     102     104     103     105     106     108     107
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2       7       6
       2       1       2       3       8       7
       .
       ...  in total, 16 shell elements defined
       .
      15       1      18      19      24      23
      16       1      19      20      25      24
$
*END

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

*KEYWORD
*TITLE
INTERFACE SEGMENTS (SECOND ANALYSIS)
$
$  LSTC Example
$
$    - The only loading on this model comes from the interface file.
$
$  Last Modified: September 18, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas

    0.0003
$
*CONTROL_ENERGY
```

```
$     hgen      rwen    slnten     rylen
         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$$$$  opifs - output interval for interface file
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
                                          0.002E-3
$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
                0.10
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
   0.00002
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
   0.00001
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$   cmpflg    ieverp    beamip

$
*DATABASE_GLSTAT

$       dt
   0.00001
$
*DATABASE_NODOUT
$       dt
   0.00001
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
       101       201       205
$
*DATABASE_RCFORC
$       dt
   0.00001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Interface
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Link the interface file to the following segments.
$
*INTERFACE_LINKING_SEGMENT
$     ssid      ifid
         3         1
$
*SET_SEGMENT
```

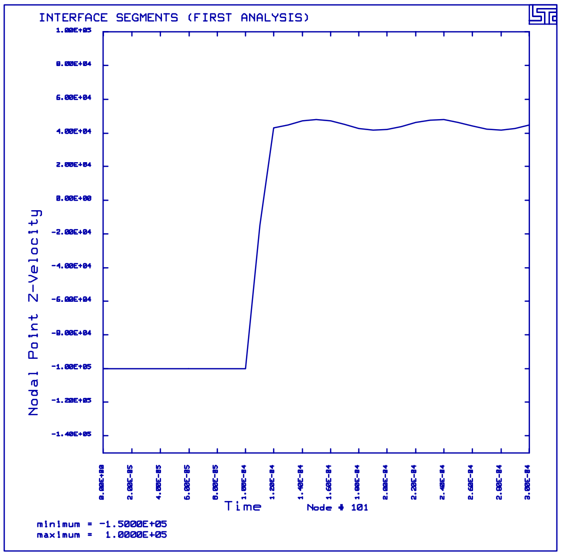
```
$      sid       da1       da2       da3       da4
         3
$       n1        n2        n3        n4        a1        a2        a3        a4
       201       202       205       204
       202       203       206       205
       204       205       208       207
       205       206       209       208
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
New Cube
         1         1         1
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         1   1.00e-8  100000.0     0.300
$
*SECTION_SOLID
$      sid    elform
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
     101    1.500000E+01    1.500000E+01    1.000000E+01       0       0
     102    2.500000E+01    1.500000E+01    1.000000E+01       0       0
       .
       ...  in total, 31 nodes defined
       .
     226    2.000000E+01    2.500000E+01    2.000000E+01       0       0
     227    2.500000E+01    2.500000E+01    2.000000E+01       0       0
$
$$$$$  Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
     101       1     201     202     205     204     210     211     214     213
     102       1     202     203     206     205     211     212     215     214
     103       1     204     205     208     207     213     214     217     216
     104       1     205     206     209     208     214     215     218     217
     105       1     210     211     214     213     219     220     223     222
     106       1     211     212     215     214     220     221     224     223
     107       1     213     214     217     216     222     223     226     225
     108       1     214     215     218     217     223     224     227     226

$
*END
```

Results:

```
taurus g=d3plot
19
rz 20 rx -80 center v
```



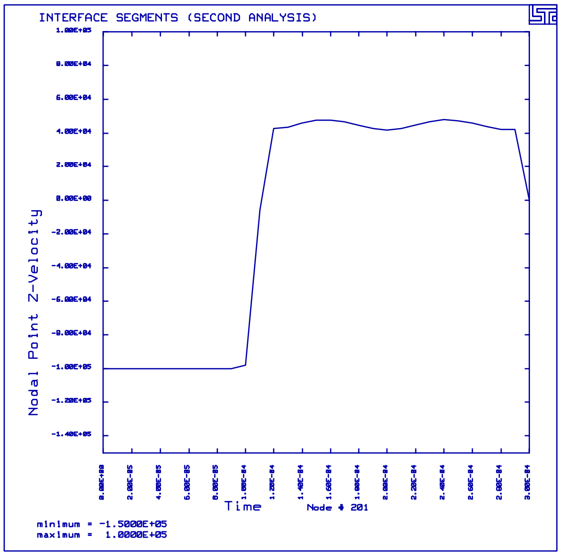
```
phs3
nodout
oset -1.5e5 1.0e5 z-vel 101
```



Results:

```
taurus g=d3plot
19
rz 20 rx -70 center v
```

```
phs3
nodout
oset -1.5e5 1.0e5 z-vel 201
```



LS-DYNA Manual Section: *LOAD_BODY_GENERALIZED

Additional Sections:

*BOUNDARY_PRESCRIBED_MOTION_NODE
*DATABASE_CROSS_SECTION_SET
*INITIAL_VELOCITY_NODE

Example: Rotating Elements

Filename: load_body.shell.k

Description:

A body has constant angular velocity. The radial vibration introduced due to the rapid deployment of the rotation is damped out in the initialization phase using dynamic relaxation.

Model:

The body measures 200 × 100 × 10 mm^3. The body consists of 2 Belytschko-Tsay elastic shell elements. The body rotates about the y-axis at 62.83 radians per second. The analysis ends at 0.1 seconds.

Input:

All nodes have an initial translational velocity based on the angular velocity v=omega x r. (*INITIAL_VELOCITY_NODE). Dynamic relaxation damps oscillations in the radial direction during the initialization (*LOAD_BODY_GENERALIZED, *DEFINE_CURVE). This essentially pre-stresses the structure and the load continues into the analysis portion. Because of the condition of constant angular velocity of the two nodes on the axis of rotation, the motion remains uniform throughout the calculation (*BOUNDARY_PRESCRIBED_MOTION_NODE). The section forces are available in the ASCII database file secforc (*DATABASE_SECFORC).

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

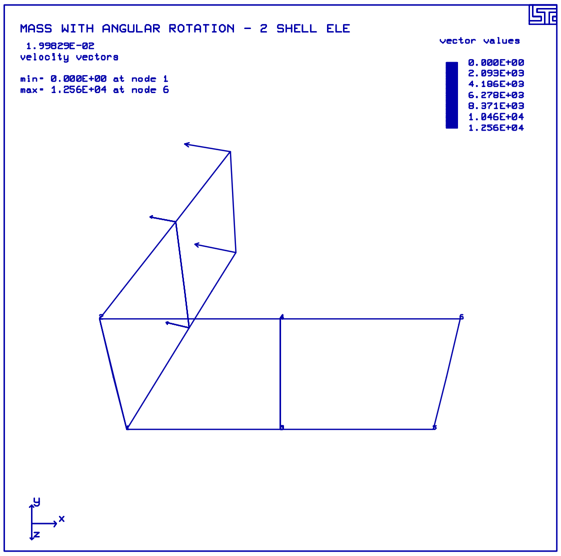
```
*KEYWORD
*TITLE
Mass with Angular Rotation - 2 Shell Elements
$
$  LSTC Example
$
$  Last Modified: September 18, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
       0.1
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
 10.00E-03
$
*DATABASE_BINARY_D3THDT
$  dt/cycl      lcdt
  0.50E-03
$
*DATABASE_ELOUT
$       dt
     0.001
$
*DATABASE_HISTORY_SHELL
$      id1       id2       id3       id4       id5       id6       id7       id8
         1         2
$
*DATABASE_GLSTAT
$       dt
     0.001
$
*DATABASE_NODOUT
$       dt
     0.001
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
         1         2         3         4         5         6
$
*DATABASE_SECFORC
$  dt/cycl      lcdt
     0.001
$

*DATABASE_CROSS_SECTION_SET
```

```
$     nsid      hsid      bsid      ssid      tsid      dsid
         1                             1
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
         1         2
$
*SET_SHELL_LIST
$      sid       da1       da2       da3       da4
         1
$     eid1      eid2      eid3      eid4      eid5      eid6      eid7      eid8
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Velocity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*INITIAL_VELOCITY_NODE
$      nid        vx        vy        vz       vxe       vye       vze
         1       0.0       0.0       0.0      0.00     62.83      0.00
         2       0.0       0.0       0.0      0.00     62.83      0.00
         3       0.0       0.0   -6283.0      0.00     62.83      0.00
         4       0.0       0.0   -6283.0      0.00     62.83      0.00
         5       0.0       0.0  -12566.0      0.00     62.83      0.00
         6       0.0       0.0  -12566.0      0.00     62.83      0.00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_NODE
$      nid       dof       vad      lcid        sf       vid
         1         6         0         1       1.0
         2         6         0         1       1.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1

$           abscissa            ordinate
               0.000               62.83
               1.000               62.83
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$

*LOAD_BODY_GENERALIZED
```

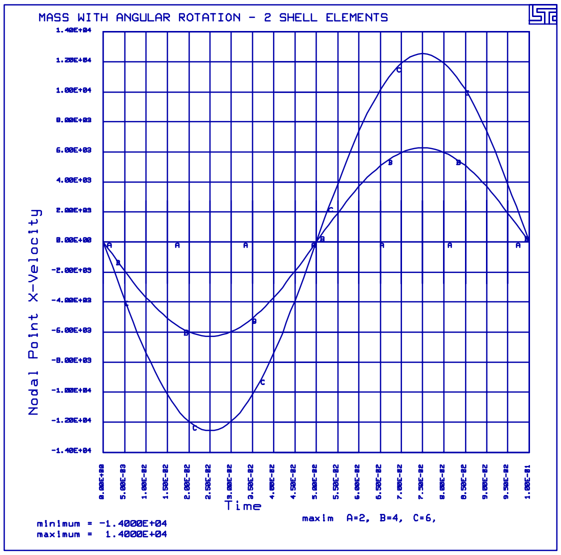
```
$       n1        n2      lcid    drlcid        xc        yc        zc
         1         6         0         2       0.0       0.0       0.0
$       ax        ay        az       omx       omy       omz
       0.0       0.0       0.0       0.0       1.0       0.0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2         1
$           abscissa            ordinate
               0.000               62.83
               1.000               62.83
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
shells
         1         1         1
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1  1.00e-08   210000.     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1                             3
$       t1        t2        t3        t4      nloc
      10.0      10.0      10.0      10.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       0
       2    0.000000E+00    1.000000E+02    0.000000E+00       6       0
       3    1.000000E+02    0.000000E+00    0.000000E+00       0       0
       4    1.000000E+02    1.000000E+02    0.000000E+00       0       0
       5    2.000000E+02    0.000000E+00    0.000000E+00       0       0
       6    2.000000E+02    1.000000E+02    0.000000E+00       0       0
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       3       4       2
       2       1       3       5       6       4
$
*END
```

Results:

```
taurus g=d3plot
19
ytran -80 rx 40 ndplt s 3 over vect velo
```



```
phs3
nodout
grid oset -1.4e4 1.4e4 x-vel 2 4 6
```



LS-DYNA Manual Section: *LOAD_BODY_Z

Additional Sections:

*RIGIDWALL_PLANAR

Example: Tire Under Gravity Loading Bounces on a Rigid Wall

Filename: load_body.gravity.k

Description:

A simple model of a tire is placed under gravity loaded and bounces on a rigid wall.

Model:

A positive gravity constant of 0.00981 mm/ms^2 is used to make the tire drop in the negative z-direction. A *RIGIDWALL_PLANAR keyword is used to define the ground. Nodes on the bottom of the tire are prevented from penetrating the rigid wall by specifying them within the *RIGIDWALL_PLANAR command (using a *SET_NODE_COLUMN keyword).

Results:

The rigid wall forces oscillate about the steady state, which is the weight of the tire (W = 0.26 kN). Curiously, the tire damps out even though no damping is specified within the model. See the example in *DAMPING_GLOBAL for an explanation and fix.

*LOAD_BODY_Z

Tire Under Gravity Loading Bounces on a Rigid Wall

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
A simple tire bouncing on the ground.
$
$  LSTC Example
$
$  Last Modified: October 10, 1997
$
$  --- GRAVITY CHECK ---
$
$   steady state is reached around 150 ms
$   m = 26.5534 kg ==> W = 0.26 kN
$   Damping oscillations around s.s., which is 0.26 kN (from RWFORC file)
$   Nodes demonstrate bouncing off ground (NODOUT)
$
$  Gravity modeled successfully using load curve and
$     BASE ACCELERATION IN Z-DIRECTION - Body Load in Z
$
$ Note: The acceleration is in the negative z-direction even though
$       all values needed to define acc. are positive.
$
$  * Shells (1 mm thick)
$  * Mild steel (with strain rate effect)
$  * Part 35 - wheel
$  * Part 36 - tire
$  * 2 discrete masses (10 kg each) at center of wheel to obtain proper weight
$  * Gap between tire and ground = 0.2 mm
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
    150.01         0       0.0       0.0       0.0
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
$
*DATABASE_BINARY_D3PLOT
$       dt       lcdt
      10.0
$
*DATABASE_BINARY_D3THDT
$       dt       lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
       0.2
$
*DATABASE_MATSUM
```

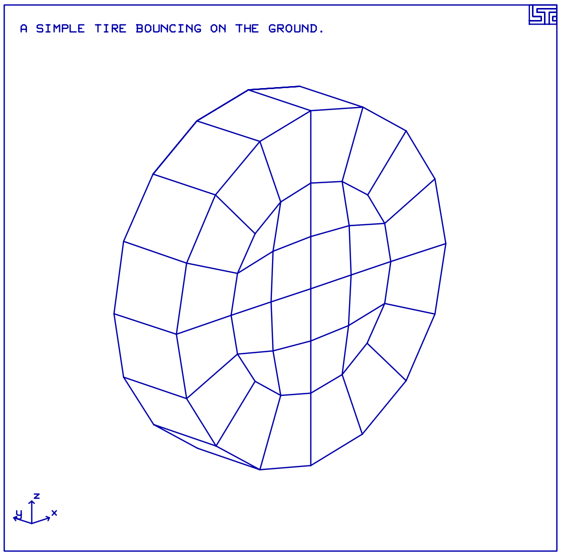
```
$       dt
       0.2
$
*DATABASE_NODOUT
$       dt
       0.2
$
*DATABASE_HISTORY_NODE

$      id1       id2       id3       id4       id5       id6       id7       id8
      8914      8746      8918
$
*DATABASE_RWFORC
$       dt
       0.2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Gravity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_BODY_Z
$
$     lcid        df    lciddr        xc        yc        zc
         1 9.810E-03
$
$
*DEFINE_CURVE
$
$     lcid      sidr      scla      sclo      offa      offo
         1
$
$           abscissa            ordinate
                0.00               1.000
             1000.00               1.000
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigid Wall - The Ground
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*RIGIDWALL_PLANAR
$     nsid    nsidex     boxid
         1         0         0
$       xt        yt        zt        xh        yh        zh      fric
       0.0       0.0    -279.2       0.0       0.0    -279.0       1.0
$
$
*SET_NODE_COLUMN
$      sid
         1
$      nid
      8901
      8904
      8911
      8912
```

```
      8913
      8914
      8919
      8920
      8921
      8922
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt

wheel
        35         1         1
tire
        36         1         1
$
$
$$$$  Materials
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 0.783E-05     200.0       0.3     0.207               0.750
$  Cowper/Symonds Strain Rate Parameters
$        C         p      lcss      lcsr
        40         5
$  Plastic stress/strain curves
     0.000     0.080     0.160     0.400     1.000
     0.207     0.250     0.275     0.290     0.300
$
$
$$$$  Sections
$
*SECTION_SHELL
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2             3.0000
$       t1        t2        t3        t4      nloc
      1.00      1.00      1.00      1.00
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
    8719 -1.16673000E+02 -6.24000000E+02 -1.16673000E+02       0       0
    8720 -1.52440000E+02 -6.24000000E+02 -6.31430000E+01       0       0
       .
       ...  in total, 82 nodes defined
```

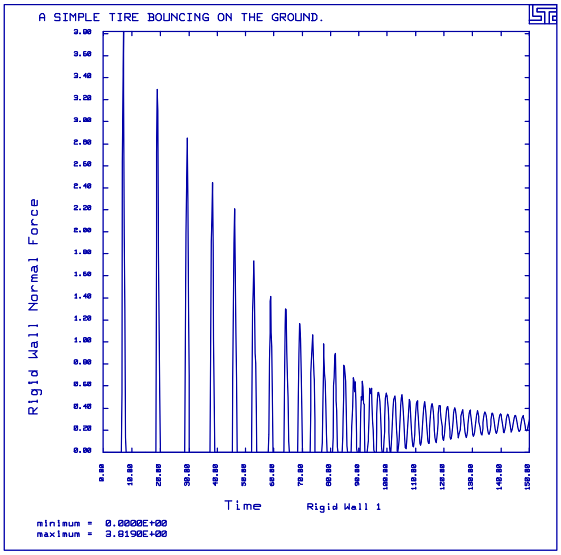
```
       .
    8931 2.790000000E+02 -7.54000000E+02 0.000000000E+00       0       0
    8932 2.577620000E+02 -7.54000000E+02 1.067690000E+02       0       0
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
    8710      35    8719    8722    8723    8720
    8711      35    8720    8723    8724    8721
       .
       ...  in total, 96 shells defined
       .
    8948      36    8928    8931    8932    8929
    8949      36    8929    8932    8926    8924
$
$$$$$$$  Nodal Mass Elements
$
*ELEMENT_MASS
$    eid     nid      mass
    8730    8730      10.0
    8746    8746      10.0
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90
ry 45 rx 20 view
```



```
phs3
rwforc
normal
```



LS-DYNA Manual Section: *MAT_FRAZER_NASH_RUBBER_MODEL

Example: Frazer-Nash Single Element

Filename: mat_fn_rubber.element.k

Description:

This model illustrates the behavior of the Frazer Nash rubber model using a single element.

Model:

The example contains a single element which measures 7.5 × 7.5 × 100. The element is constrained in the z-direction on the bottom and has prescribed velocity on the top surface.

Input:

Unitary input for any constant indicates least squares curve fitting. (*MAT_FRAZER_NASH_RUBBER). The least squares curve fit requires speciman dimensions and a stress-strain load curve. The model provides the option to stop the calculation based on maximum and minimum strain values.

Results:

The compressibility of the element and the pressure versus average strain are shown in the plots..

References:

Kenchington, D. C.

List of LS-DYNA input deck:

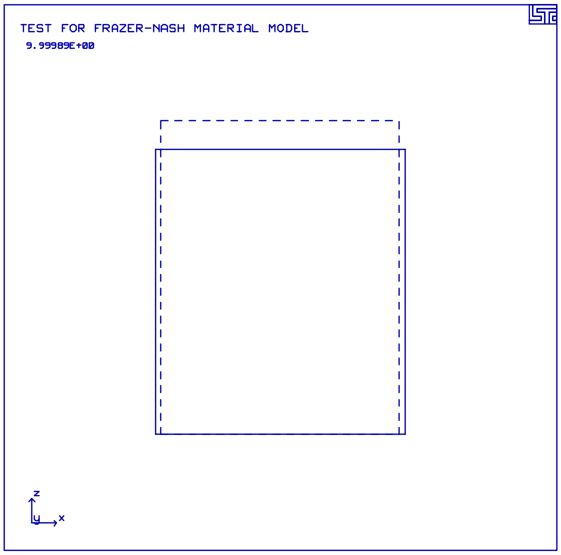
```
*KEYWORD
*TITLE
Test for Frazer-Nash Material Model
$
$  LSTC Example
$
$  Last Modified: September 18, 1997
$
$  Units: kg, mm, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
      20.0
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         1      0.05
$
*CONTROL_TIMESTEP
$   dtinit    tssfac      isdo    tslimt     dt2ms      lctm     erode     ms1st
           5.000E-01
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       0.1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
       0.1
$
*DATABASE_ELOUT
$       dt
       0.1
$
*DATABASE_HISTORY_SOLID
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
*DATABASE_GLSTAT
$       dt
       0.1
$
*DATABASE_MATSUM
$       dt
       0.1
$
*DATABASE_NODOUT
```

```
$       dt
       0.1
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions - Prescribed Motion
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_NODES
$      nid       dof       vad      lcid        sf       vid
         1         4         2         1 4.000E-02         1
         2         4         2         1 4.000E-02         1
         3         4         2         1 4.000E-02         1
         4         4         2         1 4.000E-02         1
$
*DEFINE_VECTOR
$      vid        xt        yt        zt        xh        yh        zh
         1 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00-1.000E+00
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
      0.00000000E+00      0.00000000E+00
      2.00000000E+00      7.13000011E+00
      4.00000000E+00      1.35200005E+01
      6.00000000E+00      1.86100006E+01
      8.00000000E+00      2.18700008E+01
      1.00000000E+01      2.30000000E+01
      1.20000000E+01      2.18700008E+01
      1.40000000E+01      1.86100006E+01
      1.60000000E+01      1.35200005E+01
      1.80000000E+01      7.13000011E+00
      2.00000000E+01      0.00000000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
Rubber
         1         1         1
$
$
*MAT_FRAZER_NASH_RUBBER_MODEL
$      mid        ro        pr      c100      c200      c300      c400
         1 1.254E-06     0.495 1.000E+00 0.000E+00
$
$     c110      c210      c010      c020      exit      emax      emin
 1.000E+00 0.000E+00 1.000E+00 1.000E+00 1.000E+00 9.000E-01-9.000E-01
```

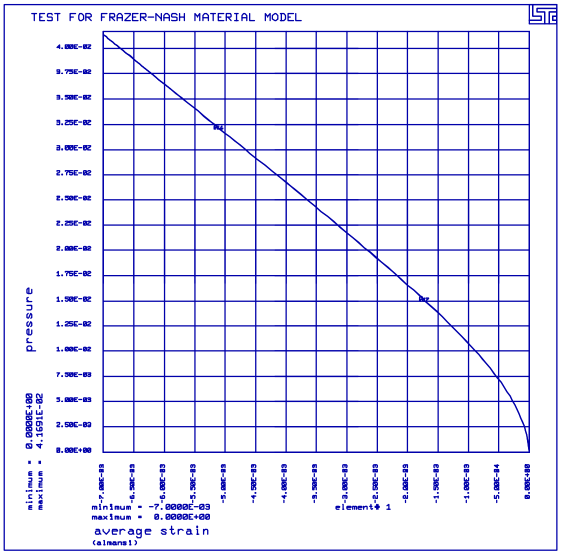
```
$
$      sgl        sw        st      lcid
 1.000E+00 1.000E+00 1.000E+00         2
$
$
*SECTION_SOLID
$      sid    elform
         1         0
$
$$$$  Force versus actual change in guage length for F_N rubber model.
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2
$           abscissa            ordinate
      0.00000000E+00      0.00000000E+00
      6.07299991E-03      3.59800004E-04
      1.24500003E-02      6.25399989E-04
      1.88100003E-02      8.85999994E-04
      2.53199991E-02      1.24600006E-03
      3.11200004E-02      1.71500002E-03
      3.71199995E-02      2.40099989E-03
      4.32099998E-02      3.35399993E-03
      4.92900014E-02      4.59800009E-03
      5.42900003E-02      5.86300017E-03
      5.93000017E-02      7.36099994E-03
      6.43299967E-02      9.10999998E-03
      6.94399998E-02      1.11400001E-02
      7.27799982E-02      1.26200002E-02
      7.60900006E-02      1.41899996E-02
      7.94499964E-02      1.59000009E-02
      8.28600004E-02      1.77500006E-02
      8.40499997E-02      1.84300002E-02
      8.52300003E-02      1.91099998E-02
      8.64199996E-02      1.98199991E-02
      8.76099989E-02      2.05400009E-02
      1.08700001E+00      2.01999998E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*NODE
$   node               x               y               z      tc      rc
       1 7.500000000E+00 0.000000000E+00 1.000000000E+01       0       0
       2 7.500000000E+00 7.500000000E+00 1.000000000E+01       0       0
       3 0.000000000E+00 7.500000000E+00 1.000000000E+01       0       0
       4 0.000000000E+00 0.000000000E+00 1.000000000E+01       0       0
       5 7.500000000E+00 0.000000000E+00 0.000000000E+00       3       0
       6 7.500000000E+00 7.500000000E+00 0.000000000E+00       3       0
       7 0.000000000E+00 7.500000000E+00 0.000000000E+00       3       0
       8 0.000000000E+00 0.000000000E+00 0.000000000E+00       3       0
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       5       6       7       8       1       2       3       4
$
*END
```

Results:

```
taurus g=d3plot
19
rx -90 angle 1 dist 1000 udg 1 state 101 view
```



```
phs2
element 1 1 gather
grid aset -7e-3 0 e2hist 8 308 1 1
```



LS-DYNA Manual Section: *MAT_PIECEWISE_LINEAR_PLASTICITY

Example: Piecewise Linear Plasticity Fragmenting Plate

Filename: mat_piecewise_linear.plate-shatter.k

Description:

A plate of 1,200 Belytschko-Tsay shell elements strikes a wall at an angle of 45 degrees from the wall normal. The impact velocity is 20,775 in/sec. and the termination time is 0.00025 seconds.

Model:

The material description contains Young's Modulus, Poisson's ratio, yield stress, hardening modulus, ultimate plastic strain, and time step size for element deletion.

Input:

One material definition for a Belytschko-Tsay shell with viscous hourglass control (*CONTROL_HOURGLASS). Young's Modulus, Poisson's ratio, yield stress and the hardening modulus are 16 Msi, 0.35, 155,000 psi, and 192,000 psi respectively. (*MAT_LINEAR_PIECEWISE_PLASTICITY). The plastic strain at failure is 32% and the failure minimum time step size is 0.3 μseconds.

Results:

The plate deforms away from the stonewall and the plate fragments.

List of LS-DYNA input deck:

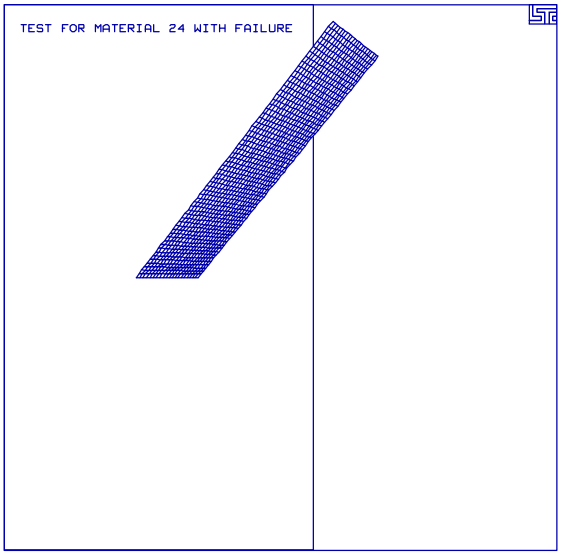
```
*KEYWORD
*TITLE
Test for Material 24 with Failure
$
$  LSTC Example
$
$  Last Modified: September 18, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 2.500E-04           5.000E-02
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
      0.01
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
 1.250E-05
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  All nodes except nodes in node set 1 are given an initial velocity.
$$$$  Node set 1 contains the nodes of the wall.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
                   1
$
$       vx        vy        vz       vxr       vyr       vzr
-1.469E+04-1.469E+04 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$      vxe       vye       vze      vxre      vyre      vzre

$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
      1282      1283      1284      1285
```

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         3         2         3                             1         1
$       fs        fd        dc        vc       vdc    penchk        bt        dt
       0.3       0.3
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*SET_PART_LIST
$      sid
         1
$     pid1      pid2      pid3
         1         2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
plate
         1         1         1
plate-tip
         2         1         1
wall
         3         1         1
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 4.1408E-4  16.00e+6      0.35   155000.   192000.      0.32   0.03e-6
$        c         p      lcss      lcsr

$     eps1      eps2      eps3      eps4      eps5      eps6      eps7      eps8

$      es1       es2       es3       es4       es5       es6       es7       es8

$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         0                   5         3         0
$       t1        t2        t3        t4      nloc
     0.125     0.125     0.125     0.125
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes 1282, 1283, 1284, 1285 are fixed - nodes of the wall.
$
```

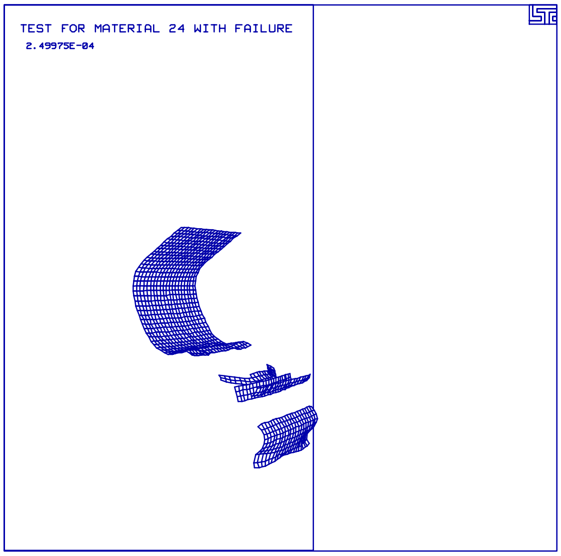
```
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       0       0
       .
       ...  in total, 1285 nodes defined
       .
    1285   -5.000000E-02   -1.000000E+01    5.000000E+00       7       7
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       2      22       1       2      23
       .
       ...  in total, 1201 shells defined
       .
    1201       3    1282    1283    1284    1285
$
*END
```

Results:

```
taurus g=d3plot
19
ry -30 dist 12 view
```



```
state 21
view
```



LS-DYNA Manual Section: *MAT_RIGID

Additonal Sections:

*DEFINE_COORDINATE_VECTOR
*LOAD_SEGMENT

Example: Rigid Sliding Block in Local Coordinate System

Filename: mat_rigid.block-slide.k

Description:

A center of mass is constrained to slide along a local coordinate system. The termination time is 0.010 seconds.

Model:

The material description references a local coordinate system to constrain the rigid block. The rigid block is free to translate along the local z axis.

Input:

The material definition is a rigid material (*MAT_RIGID). The material specifies the use of a local coordinate system, the local coordinate constraint value of 100111 (tx ty tz rx ry rz), and the local coordinate system for output. The local coordinate system specifies that the local origin is the global origin, the local x-axis point is (1.0,0.0,1.0) and the local y-axis point is (0.0,0.0,1.0) (*DEFINE_COORDINATE_VECTOR).
A shell element is defined in order to control the timestep.

Results:

The block slides along the local coordinate system.

List of LS-DYNA input deck:

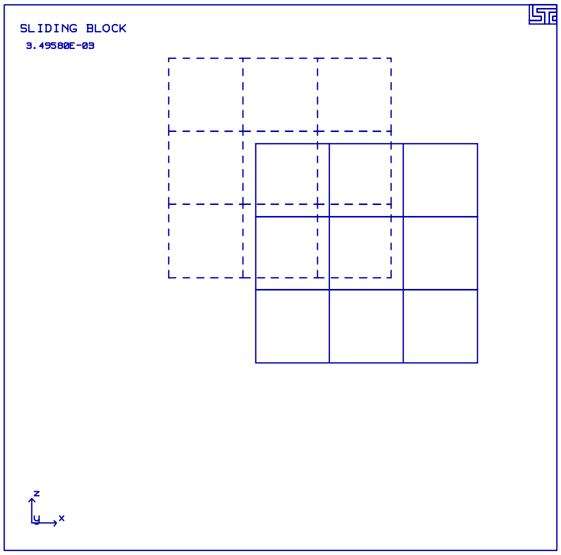
```
*KEYWORD
*TITLE
Sliding Block
$
$  LSTC Example
$
$  Last Modified: September 18, 1997
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 1.000E-02
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 5.000E-04
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
block
         1         1         1
plate
         2         2         2
$
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         1  7.85e-04 30.00e+06     0.300
$
$      cmo      con1      con2
      -1.0       1.0    100111
$
$   lco/a1        a2        a3        v1        v2       v3
       1.0
$
*DEFINE_COORDINATE_VECTOR
$      cid        xt        yt        zt        xh        yh        zh
         1 1.000E+00 0.000E+00 1.000E+00 0.000E+00 0.000E+00 1.000E+00
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         2  7.85e-04 30.00e+06     0.300
$
```

```
$
*SECTION_SOLID
$      sid    elform
         1         0
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2
$       t1        t2        t3        t4      nloc
       1.0       1.0       1.0       1.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_SEGMENT
$     lcid        sf        at        n1        n2        n3        n4
         1 1.000E+00 0.000E+00        53        49        50        54
         1 1.000E+00 0.000E+00        57        53        54        58
         1 1.000E+00 0.000E+00        61        57        58        62
         1 1.000E+00 0.000E+00        54        50        51        55
         1 1.000E+00 0.000E+00        58        54        55        59
         1 1.000E+00 0.000E+00        62        58        59        63
         1 1.000E+00 0.000E+00        55        51        52        56
         1 1.000E+00 0.000E+00        59        55        56        60
         1 1.000E+00 0.000E+00        63        59        60        64
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
           0.000E+00           1.000E+02
           1.000E-02           1.000E+02
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       0       0
       2    3.333333E-01    0.000000E+00    0.000000E+00       0       0
       3    6.666667E-01    0.000000E+00    0.000000E+00       0       0
       .
       ...  in total, 68 nodes defined
       .
      66    1.000000E+00    0.000000E+00   -1.000000E+00       0       0
      67    0.000000E+00    1.000000E+00   -1.000000E+00       0       0
      68    1.000000E+00    1.000000E+00   -1.000000E+00       0       0
$
$$$$$  Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
```

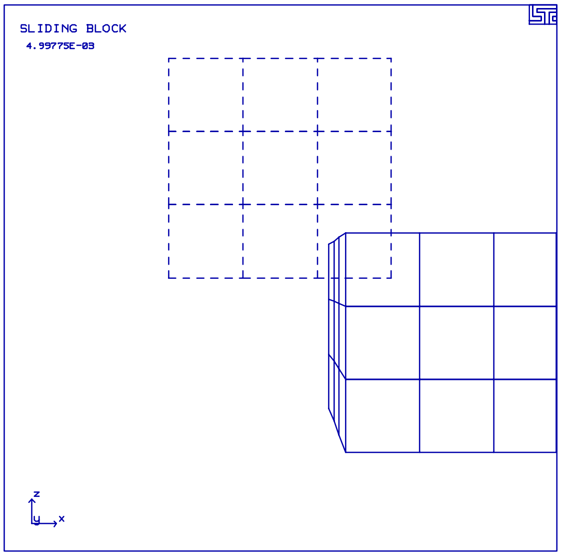
```
       1       1       1       2       6       5      17      18      22      21
       2       1       2       3       7       6      18      19      23      22
       3       1       3       4       8       7      19      20      24      23
       .
       ...  in total, 27 solids defined
       .
      25       1      41      42      46      45      57      58      62      61
      26       1      42      43      47      46      58      59      63      62
      27       1      43      44      48      47      59      60      64      63
$
$$$$$  Shell Element - used to control the timestep
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       2      65      67      68      66
*END
```

Results:

```
taurus g=d3plot
19
m 1 udg 1 rx -90 state 8 view
```



```
state 11
view
```



LS-DYNA Manual Section: *MAT_SOIL_AND_FOAM

Example: Soil and Foam Single Element

Filename: mat_soil_foam.element.k

Description:

This problem contains a single element with one degree of freedom on a side. The element compresses and expands.

Model:

The element measures 100 cubic inches. One side follows a velocity curve which results in a range of relative volume (V/Vo) 1.000 to 0.0091 to 1.441.

Input:

The foam follows a pressure volumetric strain relationship (*MAT_SOIL_AND_FOAM). The unloading behavior may follow either the unloading bulk modulus or the loading curve. The unloading in the first case follows the bulk modulus, while the unloading in the second case follows the loading curve. The material has a cutoff pressure of 0.5.

Results:

The plots show the element pressure versus time.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Foam Material Model for a Single Element
$
$  LSTC Example
$  Last Modified: September 18, 1997
$
$       This problem contains a single element with one degree of
$    freedom on a single side.  The element compresses and expands
$    following a prescribed velocity motion.
$       The material is a foam which follows a pressure volumetric
$    strain relationship.  The foam block is compressed and
$    expanded in a range of relative volume (V/Vo) from 1.0
$    to 0.0091 to 1.441.
$
$    Two types of unloading are explored:
$      1. Unloading follows the loading curve
$      2. Bulk unloading modulus is used - volumetric crushing
$
$    The foam has a tensile fracture pressure cutoff of 0.5
$
$  Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     0.250
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
     0.005
$
*DATABASE_BINARY_D3THDT
$  dt/cycl      lcdt
     0.001
$
*DATABASE_GLSTAT
$  dt/cycl      lcdt
     0.005
$
*DATABASE_ELOUT
$  dt/cycl      lcdt
     0.005
$
*DATABASE_HISTORY_SOLID
         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Motion Conditions
```

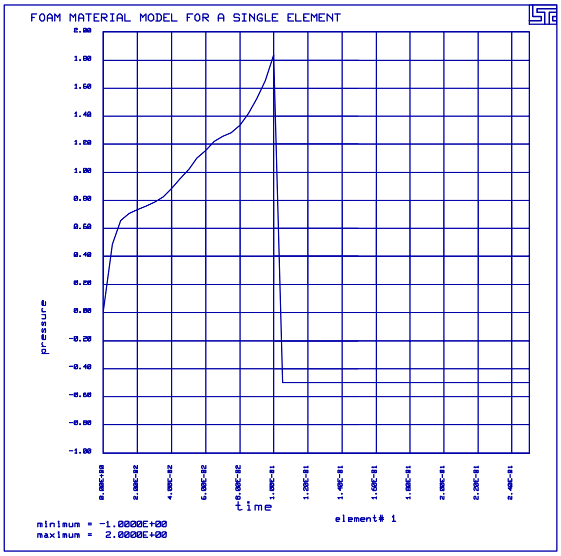
```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_PRESCRIBED_MOTION_SET
$      nid       dof       vad      lcid        sf       vid
         1         3         0         1       1.0         0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
           0.000E+00          -9.000E+02
           1.000E-01          -9.000E+02
           1.010E-01           9.000E+02
           2.500E-01           9.000E+02
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
         5         6         7         8
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
foam block
         1         1         1
$
*MAT_SOIL_AND_FOAM
$      mid        ro      bulk         g        a0        a1        a2        pc
         1 6.740E-11 5.760E+01 1.794E+01 1.200E-01 0.000E+00 0.000E+00-5.000E-01
$        f         f
$      vcr       dun
$
$ Unloading follows the loading curve
$ 1.000E+00 0.000E+00
$
$ Bulk unloading modulus is used - volumetric crushing
 0.000E+00 0.000E+00
$
$     eps1      eps2      eps3      eps4      eps5      eps6      eps7      eps8
-2.500E-02-5.000E-02-1.050E-01-3.570E-01-6.930E-01-9.160E-01-1.200E+00-1.610E+00
$
$     eps9     eps10
 0.000E+00 0.000E+00
$
$       p1        p2        p3        p4        p5        p6        p7        p8
 3.450E-01 5.170E-01 6.890E-01 8.070E-01 1.110E+00 1.240E+00 1.300E+00 1.500E+00
$
$       p9       p10
 0.000E+00 0.000E+00
$
*SECTION_SOLID
$      sid    elform
         1
```

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       7       7
       .
       ...  in total, 8 nodes defined
       .
       8    1.000000E+02    1.000000E+02    1.000000E+02       4       7
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       1       1       2       4       3       5       6       8       7
$
*END
```

Results:

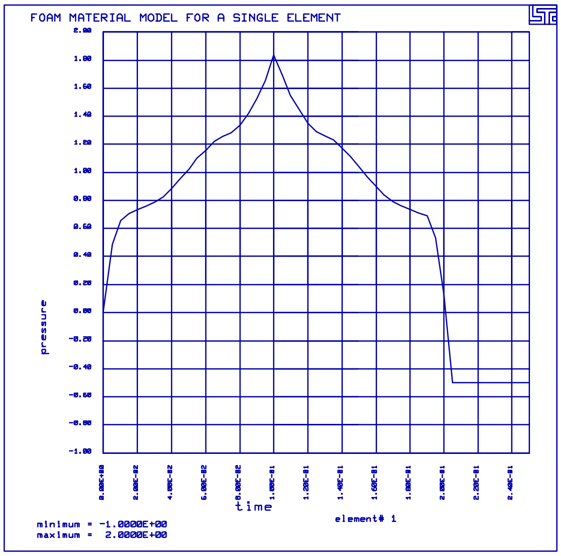
Volumetric Crushing

```
taurus g=d3plot
19
phs2 elem 1 1 gather grid oset -1 2 etime 8 1 1
```



Unloading Follows Loading Curve

```
taurus g=d3plot
phs2
elem 1 1 gather grid oset -1 2 etime 8 1 1
```



LS-DYNA Manual Section: *MAT_SPRING

Additional Sections:

*CONSTRAINED_EXTRA_NODES_SET
*CONSTRAINED_JOINT_SPHERICAL
*CONTACT_SURFACE_TO_SURFACE
*DEFINE_SD_ORIENTATION
*ELEMENT_DISCRETE
*LOAD_BODY_Z
*MAT_DAMPER_VISCOUS
*PART_INERTIA

Example: Belted Dummy with Springs

Filename: mat_spring.belted-dummy.k

Description:

This is a simulation of the interaction between a dummy and seating system. The dummy has an initial velocity, base vehicle acceleration, and decelerated base.

Model:

The dummy consists of 15 ellipsoidal rigid bodies connected through cylindrical joints, springs and dampers. The base of the seat belts and the seat decelerates backwards relative to the dummy.

Input:

The dummy consists of rigid bodies 1 through 15. Materials 16 through 20 define the seat and material 21 and 22 define the seat belt. The rigid bodies are constrained with respect to each other with spherical joints (*CONSTRAINED_JOINT_SPHERICAL). Discrete springs and dampers between the rigid body provide the relative stiffness and viscosity. The initial velocity of all nodes is 14.8 units, while the acceleration of the seat and belt ends follow an acceleration curve in the opposite direction.

Results:

LS-DYNA predicts that the dummy slides under the seat belts.

Reference:

Stillman, D. W.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Belted Dummy
$
$  LSTC Example
$
$  Last Modified: September 19, 1997
$
$  Units: kg, m, s, N, Pa, Joule
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 1.200E-01
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
                                                                     2
$   usrstr    usrfac     nsbcs    interm    xpenen

$
*CONTROL_TIMESTEP
$   dtinit      scft      isdo    tslimt      dtms      lctm     erode     ms1st
 0.000E+00 8.000E-01         0 0.000E+00 0.000E+00         0    0
$
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl      lcdt
 2.500E-03
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  All nodes are given an initial velocity.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
         0
$
$       vx        vy        vz       vxr       vyr       vzr
 1.480E+01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

```
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  The base of the seat decelerates backwards relative to the dummy.
$
*BOUNDARY_PRESCRIBED_MOTION_SET
$     nsid       dof       vad      lcid        sf       vid
         1         1         1        50     -1.00         1
$
*SET_NODE_LIST
$      sid       da1       da2       da3       da4
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
      1763      1764      1765      1766      1767      1768      1769      1770
      1771      1772      1773      1774      1775      1776      1777      1778
      1779      1780      1781      1782      1783      1784      1785      1786
      1787      1788      1789      1792      1795      1904      1906      1908
      1909      1910      1997      1998      1999      2043
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
        50
$           abscissa            ordinate
      0.00000000E+00      0.00000000E+00
      4.00000019E-03      4.41500015E+01
      6.00000005E-03      2.94300003E+01
      9.99999978E-03      7.84800034E+01
      1.35000004E-02      4.41500015E+01
      1.79999992E-02      1.37300003E+02
      2.34999992E-02      1.66800003E+02
      3.09999995E-02      2.35399994E+02
      3.40000018E-02      2.35399994E+02
      3.59999985E-02      2.55100006E+02
      3.99999991E-02      2.60000000E+02
      4.19999994E-02      2.60000000E+02
      4.45000008E-02      2.69799988E+02
      4.69999984E-02      2.60000000E+02
      4.89999987E-02      2.60000000E+02
      5.15000001E-02      2.55100006E+02
      5.40000014E-02      2.55100006E+02
      7.99999982E-02      1.22599998E+02
      9.00000036E-02      4.90499992E+01
      9.49999988E-02     -9.81000042E+00
      9.74999964E-02     -2.45300007E+01
      1.03000000E-01      1.47200003E+01
      1.08999997E-01     -1.47200003E+01
      1.15000002E-01     -9.81000042E+00
      1.19499996E-01     -4.90999985E+00
      1.12499997E-01     -9.81000042E+00
      1.29999995E-01     -2.45000005E+00
      1.41000003E-01     -1.96200008E+01
      1.49000004E-01     -2.45000005E+00
      1.51999995E-01     -1.47200003E+01
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Gravity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*LOAD_BODY_Z
```

```
$     lcid        sf    lciddr
        51      1.00         0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
        51
$          abscissa            ordinate
      0.00000000E+00                9.81
      1.51999995E-01                9.81
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  The segment sets associated with these contacts are located at the end
$$$$  of this file.
$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2         0         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt
 6.200E-01
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*CONTACT_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         4         0         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt
 6.200E-01
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
*CONTACT_SURFACE_TO_SURFACE
         5         6         0         0
 6.200E-01

$
*CONTACT_SURFACE_TO_SURFACE
         7         8         0         0
 8.000E-01

$
*CONTACT_SURFACE_TO_SURFACE
         9        10         0         0
 1.000E+00

$
*CONTACT_SURFACE_TO_SURFACE
        11        12         0         0
 8.000E-01

$
*CONTACT_SURFACE_TO_SURFACE
        13        14         0         0
 8.800E-01

$
```

```
*CONTACT_SURFACE_TO_SURFACE
        15        16         0         0
 8.800E-01

$
*CONTACT_SURFACE_TO_SURFACE
        17        18         0         0
 1.600E-01

$
*CONTACT_SURFACE_TO_SURFACE
        19        20         0         0
 8.800E-01

$
*CONTACT_SURFACE_TO_SURFACE
        21        22         0         0
 0.000E+00

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constraints
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONSTRAINED_JOINT_SPHERICAL
$       n1        n2        n3        n4        n5       rps      damp
        99       227         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       228       405         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       406       865         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       866       971         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       407       537         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       538       685         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       408       603         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       604       763         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       972      1097         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
      1098      1497         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
      1498      1645         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
       973      1317         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
      1318      1579         0         0         0         0 0.000E+00
*CONSTRAINED_JOINT_SPHERICAL
      1580      1733         0         0         0         0 0.000E+00
$
$
*CONSTRAINED_EXTRA_NODES_SET
$      pid      nsid
         1         2
```

```
$
*SET_NODE_LIST
$      sid
         2
$     nid1      nid2      nid3      nid4      nid5
        99       100       101       102
$
       .
       ...  in total, 15 extra_nodes_set & set_node_list pairs defined
       .
$
*CONSTRAINED_EXTRA_NODES_SET
$      pid      nsid
         2         3
$
*SET_NODE_LIST
$      sid
         3
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       227       228       229       230       231       232       233       234
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Spring Orientation Vectors and Curves
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DEFINE_SD_ORIENTATION
$      vid       iop        xt        yt        zt      nid1      nid2

         1         2 0.000E+00 0.000E+00 0.000E+00       100       229
         2         2 0.000E+00 0.000E+00 0.000E+00       101       230
         3         2 0.000E+00 0.000E+00 0.000E+00       102       231
       .
       ...  in total, 42 sd_orientation vectors defined
       .
        40         2 0.000E+00 0.000E+00 0.000E+00      1584      1734
        41         2 0.000E+00 0.000E+00 0.000E+00      1585      1735
        42         2 0.000E+00 0.000E+00 0.000E+00      1586      1736
$
$$$$  Define Curves
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$          abscissa            ordinate
     -1.71000004E+00     -5.38000000E+02
     -7.09999979E-01     -8.47500000E+01
     -6.80000007E-01     -7.76600037E+01
     -6.60000026E-01     -7.10599976E+01
     -5.89999974E-01     -5.36800003E+01
     -5.00000000E-01     -4.05800018E+01
     -3.89999986E-01     -2.99799995E+01
     -2.09999997E-02     -4.65000010E+00
      0.00000000E+00      0.00000000E+00
      2.09999997E-02      4.65000010E+00
      3.89999986E-01      2.99799995E+01
      5.00000000E-01      4.05800018E+01
      5.89999974E-01      5.36800003E+01
```

```
      6.60000026E-01      7.10599976E+01
      6.80000007E-01      7.76600037E+01
      7.09999979E-01      8.47500000E+01
      1.71000004E+00      5.38000000E+02
$
       .
       ...  load curves 2-48 also defined here
       .
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
        49
$           abscissa            ordinate
     -1.00000000E+03     -1.00000000E+00
     -5.00000000E-01     -1.00000000E+00
      5.00000000E-01      1.00000000E+00
      1.00000000E+03      1.00000000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART_INERTIA
material type # (rigid)
$      pid       sid       mid     eosid      hgid    adpopt
         1         1         1         0
$       xc        yc        zc        tm      ircs
-1.739E-01 0.000E+00 6.523E-01 4.535E+00
$      ixx       ixy       ixz       iyy       iyz       izz
 1.590E-02 0.000E+00 1.424E-04 2.400E-02 0.000E+00 2.210E-02
$      vtx       vty       vtz       vrx       vry       vrz
 1.480E+01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
       .
       ...  part_inertia pid's 2-15 also defined here
       .
$
*PART_INERTIA
material type # (rigid)
        15        15        15         0
 7.873E-01-7.999E-02-1.021E-01 1.250E+00
 1.000E-02 0.000E+00 0.000E+00 1.000E-02 0.000E+00 1.000E-02
 1.480E+01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
material type # 1  (elastic)
        16        16        16       0
material type # 1  (elastic)
        17        17        17       0
material type # 1  (elastic)
        18        18        18       0
material type # 1  (elastic)
        19        19        19       0
material type # 1  (elastic)
        20        20        20       0
part-21
        21        21        21       0
```

```
part-22
        22        22        22         0
spring  101
       101       101       101
$
       .
       ...  spring pid's 102-207 also defined here
       .
$
spring  208
       208       208       208
$
$$$$$$$$  Materials
$
$
$$$$  Rigid Materials
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         1 4.064E+03 4.000E+08 3.000E-01 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
       .
       ...  mat_rigid mid's 2-14 also defined here
       .
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
        15 2.000E+03 4.000E+08 3.000E-01 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$
$$$$  Elastic Materials
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        16 4.646E+03 4.000E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        17 4.646E+03 4.000E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        18 4.646E+03 4.000E+09 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        19 4.646E+03 4.000E+08 3.000E-01

*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        20 2.000E+03 4.100E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        21 2.000E+03 4.100E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
        22 4.000E+03 2.000E+08 3.000E-01
$
$
$$$$  Nonlinear Elastic Spring Materials
$
*MAT_SPRING_NONLINEAR_ELASTIC
```

```
       101         1
$
       .
       ...  mat_spring_nonlinear_elastic mid's 101-142 also defined here
       .
$
*MAT_SPRING_NONLINEAR_ELASTIC
       142        42
$
$
$$$$  Viscous Damper Materials
$
*MAT_DAMPER_VISCOUS
       143 2.300E+00
$
       .
       ...  mat_damper_viscous mid's 143-184 also defined here
       .
$
*MAT_DAMPER_VISCOUS
       184 1.000E+00
$
$
$$$$  Nonlinear Viscous Damper Materials
$
*MAT_DAMPER_NONLINEAR_VISCOUS
       185        43
$
       .
       ...  mat_damper_nonlinear_viscous mid's 185-208 also defined here
       .
$
*MAT_DAMPER_NONLINEAR_VISCOUS
       208        49
$
$
$$$$$$$$  Sections
$
$
$$$$  Shell Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         0 0.000E+00 0.000E+00 0.000E+00
$       t1        t2        t3        t4      nloc
 1.000E-02 1.000E-02 1.000E-02 1.000E-02 0.000E+00
$
       .
       ...  shell sid's 2-21 also defined here
       .
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
        22         0 0.000E+00 0.000E+00 0.000E+00
 1.000E-02 1.000E-02 1.000E-02 1.000E-02 0.000E+00
$

$
$$$$  Spring-Damper Sections

$
*SECTION_SPRING-DAMPER
       101         1 0.000E+00 0.000E+00 0.000E+00 0.000E+00
```

```
 0.000E+00 0.000E+00
$
       .
       ...  spring-damper sid's 102-207 also defined here
       .
$
*SECTION_SPRING-DAMPER
       208         1 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1-2.416931689E-01-3.286990896E-02 5.876007080E-01       0       0
       2-2.475307435E-01-1.784761623E-02 5.820254087E-01       0       0
       3-2.498186529E-01-1.089885016E-03 5.798402429E-01       0       0
       .
       ...  in total, 2043 nodes defined
       .
    2041-5.439429283E-01 2.696031034E-01 6.014695168E-01       0       0
    2042-5.649484396E-01 2.777405977E-01 6.089934111E-01       0       0
    2043-5.859540105E-01 2.858780622E-01 6.165173650E-01       5       0
$
$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       4       5       2
       2       1       2       5       6       3
       3       1       4       7       8       5
       .
       ...  in total, 1950 shells defined
       .
    1948      22     394     357     365     403
    1949      22     403     365     367     404
    1950      22     404     367     369     379
$
$$$$  Discrete Elements
$
*ELEMENT_DISCRETE
$    eid     pid      n1      n2     vid               s      pf          offset
       1     101       1     129       1  0.00000000E+00       1
       2     102       1     129       2  0.00000000E+00       1
       3     103       1     129       3  0.00000000E+00       1
       .
       ...  in total, 108 discrete elements defined
       .
     106     206    1505    1675      41  0.00000000E+00       1
     107     207    1505    1675      42  0.00000000E+00       1
     108     208    1505    1675      40  0.00000000E+00       1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Segment sets for the contacts defined previously.
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*SET_SEGMENT
$      sid       da1
         1         4
$       n1        n2        n3        n4
      1780      1783      1784      1781
      1783      1786      1787      1784
      1781      1784      1785      1782
      1784      1787      1788      1785
       .
       ...  in total, 22 segment sets defined for the contacts
       .
$
*END
```

Results:

taurus g=d3plot
19
rx -90 center view

state 49
center
view

LS-DYNA Manual Section: *MAT_TRANSVERSELY_ANISOTROPIC

Additional Sections:

*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
*LOAD_SHELL_ELEMENT

Example: Rectangular Cup Drawing

Filename: mat_transversely_anisotropic.cup-draw.k

Description:

This problem includes three tools a punch, a holder and a die, and a blank. The blank is drawn by moving the punch downwards to form around the die. The blank uses the *MAT_TRANSVERSELY_ANISOTROPIC_ELASTIC_PLASTIC material model.

Model:

The *BOUNDARY_PRESCRIBED_MOTION_RIGID keyword is used to give the punch a prescribed velocity in the z-direction. All shells on the holder are given a pressure load to clamp down on the blank (*LOAD_SHELL_ELEMENT). One way surface to surface contact is defined between the major parts in the model. Because of symmetry, only 1/4 of the system is modeled.

Results:

A contour plot of the effective stress on the blank after drawing is shown.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Rectangular Cup Drawing
$
$  LSTC Example
$
$  Last Modified: October 14, 1997
$
$$$   Original model received from Cray Research (John Gee)  - 7/19/95
$
$  The model consists of 4 parts:
$     1 - blank  (part that gets formed)
$     2 - die    (fixed part that forms the shape)
$     3 - holder (holds the blank from top)
$     4 - punch  (pushes down onto the blank)
$
$  The die, holder and punch are all rigid materials.
$
$  The blank is Mat #37
$       MAT_TRANSVERSELY_ANISOTROPIC_ELASTIC_PLASTIC
$
$  Units:   ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endeng    endmas
      .015
$
*CONTROL_CONTACT
$   slsfac    rwpnal    islchk    shlthk    penopt    thkchg     orien
       0.1       0.0         1         2         0         2         2
$   usrstr    usrfac     nsbcs    interm    xpenen
         0         0         0         0       4.0
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         1         2         0
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3         1         1       0.0
$
*CONTROL_SHELL
$   wrpang    itrist     irnxx    istupd    theory       bwc     miter
      20.0         1        -1         1         2         2
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
     0.002
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
```

```
         0         0         3         1         1         1         1         1
$   cmpflg    ieverp    beamip
         0         1         0
$
*DATABASE_GLSTAT
    0.0001
$
*DATABASE_RCFORC

    0.0001
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Curves
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1         0       1.0       1.0   2.0E-03       0.0
$
$    abscissa       ordinate
 0.000000E+00,  0.000000E+00
 3.000000E-04,  1.644664E+00
 6.000000E-04,  3.287704E+00
       .
       ...  in total, 102 points defined for this curve
       .
 2.970000E-02,  1.644661E+00
 3.000000E-02,  0.000000E+00
 100.0000E-03,  0.000000E+00
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2
$ absc   ordin
 0.0000, 127.55
 0.00598, 129.69
 0.0119, 156.99
 0.0178, 171.96
 0.0180, 182.50
 0.0296, 205.95
 0.0583, 252.14
 0.0860, 283.72
 0.1345, 319.43
 0.1660, 336.81
 0.2150, 358.25
 0.2620, 376.45
 0.3070, 389.14
 0.3290, 394.86
 0.6000, 394.86
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         3
$ absc     ordin
   0.0,      0.0
   1.0, 0.413E05
```

```
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         4
$ absc     ordin
   0.0,      0.0
   1.0,      1.0
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         5
$        absc     ordin
          0.0,      0.0
      1.0E-03,      5.0
    150.0E-03,      5.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Motion Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$   The punch (part 4) is given a prescribed velocity in the z-direction.
$$$   Velocity follows curve 1 (scaled by -20).
$
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      nid       dof       vad      lcid        sf       vid
         4         3         0         1     -20.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$$  PARTS
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
blank
         1         1         1
die
         2         2         2
holder
         3         2         3
punch
         4         2         3
$
$
$$$$$  Materials
$
*MAT_TRANSVERSELY_ANISOTROPIC_ELASTIC_PLASTIC
$
$  mat #37
$      mid        ro         e        pr      sigy      etan         r     hlcid
         1 0.787E-08 0.207E+06     0.280     127.6       0.0       1.0       2.0
$
```

```
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         2 0.787E-08 0.207E+06     0.280
$
$      cmo      con1      con2
       1.0         7         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         3 0.787E-08 0.207E+06     0.280       0.0       0.0
$
$      cmo      con1      con2
       1.0         4         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
$
$$$$$  Sections
$
*SECTION_SHELL

$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2       1.0       3.0
$
$       t1        t2        t3        t4      nloc
      0.80      0.80      0.80      0.80
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         2       1.0       3.0
$       t1        t2        t3        t4      nloc
1.0000E+03 1.000E+00 1.000E+00 1.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$   Note: Segment sets for these contacts are at the end of the deck.
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         3         2         0         0
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
     0.000     0.000       0.0       0.0       5.0         0       0.0  30.0E-03
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
       1.0       1.0      0.80      1.00       1.0       1.0       1.0       1.0
$
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
         5         4         0         0
     0.000     0.000       0.0       0.0       5.0         0       0.0  30.0E-03
```

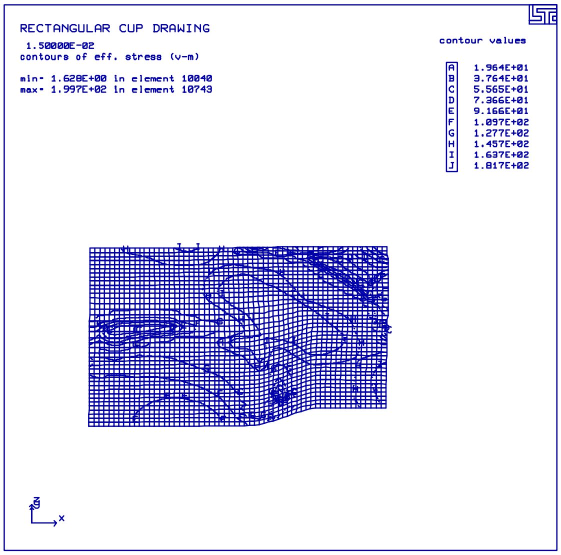
```
       1.0       1.0      0.80      1.00       1.0       1.0       1.0       1.0
$
$
*CONTACT_ONE_WAY_SURFACE_TO_SURFACE
         7         6         0         0
     0.000     0.000       0.0       0.0       5.0         0       0.0  30.0E-03
       1.0       1.0      0.80      1.00       1.0       1.0       1.0       1.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_SPC_NODE
     10061         0         1         1         0         0         0         0
     10122         0         1         0         0         0         0         0
       .
       ...  in total, 101 SPC's defined
       .
     10059         0         0         1         0         0         0         0
     10060         0         0         1         0         0         0         0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Loading
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  All shells on the holder (part 3) are given a pressure boundary condition
$$$$  to clamp down on the blank.  The pressure follows load curve 5.
$
*LOAD_SHELL_ELEMENT
$     esid      lcid        sf        at
     30001         5 -1.00E+00       0.0
     30002         5 -1.00E+00       0.0
       .
       ...  in total, 448 shell element loads defined
       .
     30447         5 -1.00E+00       0.0
     30448         5 -1.00E+00       0.0
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
   20001 6.700000000E+01 1.624058654E-14 -1.00000000E+01
   20002 6.734069807E+01 2.462506303E-10 -7.41197155E+00
       .
       ...  in total, 4266 nodes defined
       .
   12500 1.666667211E+00 8.500000000E+01 1.000000000E+00
```

```
   12501 0.000000000E+00 8.500000000E+01 1.000000000E+00
$
$$$$$$$$$    SHELL ELEMENTS
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
   40303       4   40333   40191   40001   40001
   40304       4   40334   40333   40001   40001
       .
       ...  in total, 4028 shells defined
       .
   40411       4   40416   40417   40444   40443
   40412       4   40417   40418   40445   40444
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Segment Sets for Contacts
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*SET_SEGMENT
$      sid       da1
         3      2400
$       n1        n2        n3        n4
     10001     10002     10063     10062
     10062     10063     10124     10123
       .
       ...  in total, 2400 segments defined
       .
     12378     12379     12440     12439
     12439     12440     12501     12500
$
  .
  ...  in total, 6 *SET_SEGMENT's defined (only the one above shown)
  .
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90
state 20 view
```

```
m 1
numc 10 mono
rx 25 contour 9
```



LS-DYNA Manual Section: *RIGIDWALL_GEOMETRIC_SPHERE_MOTION

Example: Rigid Wall Sphere Impacts a Plate

Filename: rigidwall_geometric_sphere.plate.k

Description:

A “Stonewall” - sphere impacts an elastic plate. (The sphere will not be shown in LS-TAURUS.)

Model:

The plate has an elastic material model with Belytschko-Tsay shell formulation. The plate is $40 \times 40 \times 2$ mm^3. The sphere has a radius of 8 mm and its center is 9 mm above the plate. The sphere moves towards the plate with a prescribed displacement resulting in a velocity of velocity of 3 mm/second.

Input:

A spherical stonewall surface represents the true geometry of the ball. (*RIGIDWALL_GEOMETRIC_SPHERE_MOTION). The stonewall cards contain direction and load curve number defining the motion. All nodes of the plate are prevented from penetrating the sphere

Reference:

Schweizerhof, K. and Weimer, K.

*RIGIDWALL_GEOMETRIC_SPHERE_MOTION

Rigid Wall Sphere Impacts a Plate

List of LS-DYNA input deck:

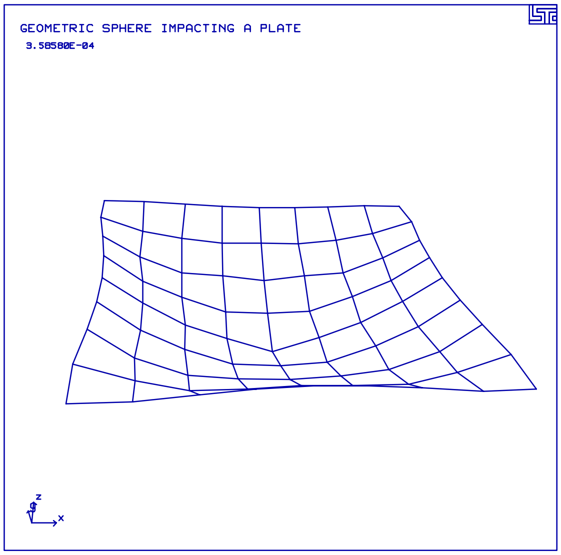
```
*KEYWORD
*TITLE
Geometric Sphere Impacting a Plate
$
$  LSTC Example
$
$  Last Modified: September 19, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
  .5000E-3
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 0.0200E-3
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
                                       1
$   cmpflg    ieverp    beamip

$
*DATABASE_RWFORC
$       dt
  0.005e-4
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigidwalls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*RIGIDWALL_GEOMETRIC_SPHERE_MOTION
$     nsid    nsidex     boxid
         0
$
$       xt        yt        zt        xh        yh        zh      fric
      20.0      20.0       9.0      20.0      20.0       0.0
$
$   radsph
       8.0
$
$     lcid       opt        vx        vy        vz
```

```
         1         1       0.0       0.0      -1.0
$
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         1
$           abscissa            ordinate
                 0.0                 0.0
              0.0005                15.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
plate
         1         1         1
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1  2.00e-08   100000.     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333       2.0       3.0
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Nodes on the outside edges of the plate are constrained in z-translation.
$
*NODE
$   node               x               y               z      tc      rc
       1    0.000000E+00    0.000000E+00    0.000000E+00       3       0
       2    5.000000E+00    0.000000E+00    0.000000E+00       3       0
       3    1.000000E+01    0.000000E+00    0.000000E+00       3       0
       .
       ...  in total, 81 nodes defined
       .
      79    3.000000E+01    4.000000E+01    0.000000E+00       3       0
      80    3.500000E+01    4.000000E+01    0.000000E+00       3       0
      81    4.000000E+01    4.000000E+01    0.000000E+00       3       0
$
$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2      11      10
       2       1       2       3      12      11
       3       1       3       4      13      12
```

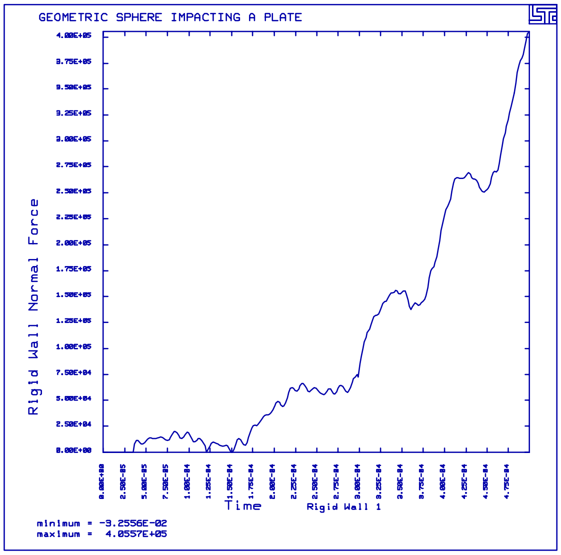
```
       .
       ...  in total, 64 shells defined
       .
      62        1      69      70      79      78
      63        1      70      71      80      79
      64        1      71      72      81      80
$
*END
```

Results:

```
taurus g=d3plot
19
rx -60 ry 10 state 19 view
```



```
phs3
rwforc
normal
```



LS-DYNA Manual Section: *RIGIDWALL_PLANAR

Additional Sections:

*INITIAL_VELOCITY_NODE

Example: Rotating Shell Strikes Rigid Wall

Filename: rigidwall_planar.shell.k

Description:

A rotating shell element strikes and rebounds from a rigid wall surface. The plate is modeled with shell elements for viewing in LS-TAURUS. This does not affect the calculation.

Model:

The shell element has an elastic material model with Belytschko-Tsay shell formulation. The plate measures $10 \times 10 \times 2$ mm^3. The plate has an initial velocity of 100,000 mm/second in negative z-direction and an initial angular velocity of 100,000 radians/second about the y-axis. The rigid surface is modeled by an infinite smooth stonewall surface.

Input:

Nodes requiring initial velocity are specified with *INITIAL_VELOCITY_NODE. The location of the “Stonewall” is in the x-y plane with z=0 (*RIGIDWALL_PLANAR). The 4 nodes belonging to the shell element are slave nodes in the stonewall definition. The velocity components of the slave nodes in the normal direction to the stonewall are reset to zero at the moment of impact.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

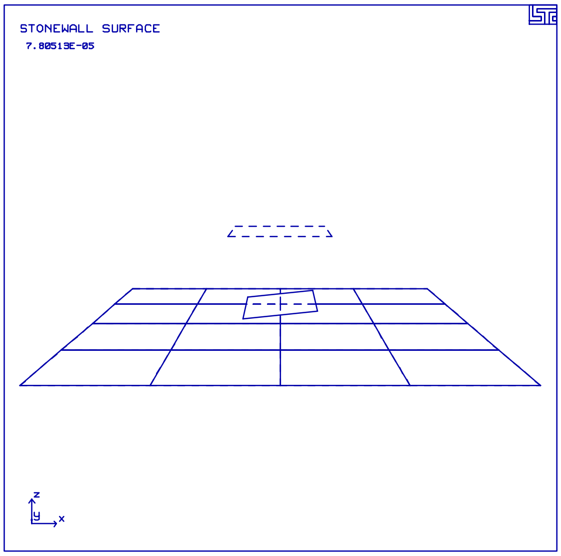
```
*KEYWORD
*TITLE
STONEWALL SURFACE
$
$  LSTC Example
$
$  Last Modified: September 23, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
 2.000E-04
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 1.000E-05
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
 2.000E-03
$
*DATABASE_GLSTAT
$       dt
   4.0e-06
$
*DATABASE_NODOUT
$       dt
   4.0e-06
$
*DATABASE_HISTORY_NODE
$        i         i         i         i         i         i         i         i
$      id1       id2       id3       id4       id5       id6       id7       id8
        12        13       101
$
*DATABASE_RWFORC
$       dt
   4.0e-06
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigidwalls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
```

```
$$$$  The nodes in set 1 (nodes of the moving shell) are prevented from
$$$$  penetrating the rigidwall.
$
*RIGIDWALL_PLANAR
$     nsid    nsidex     boxid
         1
$
$       xt        yt        zt        xh        yh        zh      fric

    20.000    20.000     0.000  20.00000  20.00000   100.000
$
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       101       102       103       104
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  Nodes of the moving shell are given an initial tran and rot velocity.
$
*INITIAL_VELOCITY_NODE
$      nid        vx        vy        vz       vxe       vye       vze
       101 0.000E+00 0.000E+00-1.000E+05 0.000E+00 1.000E+05 0.000E+00
       102 0.000E+00 0.000E+00-1.000E+05 0.000E+00 1.000E+05 0.000E+00
       103 0.000E+00 0.000E+00-1.000E+05 0.000E+00 1.000E+05 0.000E+00
       104 0.000E+00 0.000E+00-1.000E+05 0.000E+00 1.000E+05 0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
wall
         1         1         1
moving-shell
         2         2         2
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         1 1.000E-08 1.000E+05 3.000E-01
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
         2 1.000E-08 1.000E+05 3.000E-01
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
```

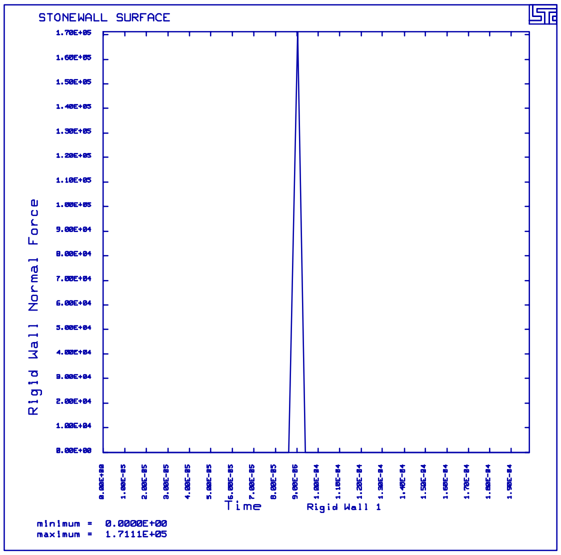
```
         1         2   0.83333 2.000E+00 3.000E+00 0.000E+00
$       t1        t2        t3        t4      nloc
 1.000E+00 1.000E+00 1.000E+00 1.000E+00 0.000E+00
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         2   0.83333 2.000E+00 3.000E+00 0.000E+00
$       t1        t2        t3        t4      nloc
 2.000E+00 2.000E+00 2.000E+00 2.000E+00 0.000E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1 0.000000000E+00 0.000000000E+00 0.000000000E+00       7       0
       2 1.000000000E+01 0.000000000E+00 0.000000000E+00       7       0
       3 2.000000000E+01 0.000000000E+00 0.000000000E+00       7       0
       .
       ...  in total, 29 nodes defined
       .
     102 2.500000000E+01 1.500000000E+01 1.000000000E+01       0       0
     103 1.500000000E+01 2.500000000E+01 1.000000000E+01       0       0
     104 2.500000000E+01 2.500000000E+01 1.000000000E+01       0       0
$
$$$$$  Shell Elements - All shells except 101 are for display of the Rigidwall
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       2       7       6
       2       1       2       3       8       7
       3       1       3       4       9       8
       4       1       4       5      10       9
       5       1       6       7      12      11
       6       1       7       8      13      12
       7       1       8       9      14      13
       8       1       9      10      15      14
       9       1      11      12      17      16
      10       1      12      13      18      17
      11       1      13      14      19      18
      12       1      14      15      20      19
      13       1      16      17      22      21
      14       1      17      18      23      22
      15       1      18      19      24      23
      16       1      19      20      25      24
     101       2     101     102     104     103
$
*END
```

Results:

```
taurus g=d3plot
19
udg 1 state 9 rx -80 view
```



```
phs3
rwforc
normal
```



LS-DYNA Manual Section: *RIGIDWALL_PLANAR_FORCES

Example: Cube Rebounding

Filename: rigidwall_planar.cube.k

Description:

A cube impacts and rebounds from a rigid plate (“Stonewall”). The plate is modeled with shell elements for viewing in LS-TAURUS.

Model:

The cube measures $10 \times 10 \times 10$ mm^3 and is 10 mm above the rigid plate. It has 8 brick elements with elastic material properties. The initial velocity of the cube is 100,000 mm/second. The plate is an infinite “Stonewall” - surface

Input:

The box option defines the nodes with the initial velocity (*DEFINE_BOX, *INITIAL_VELOCITY). The location of the “Stonewall” is at z=0 (*RIGIDWALL_PLANAR_FORCES). The nine nodes on the lower side of the cube are slave nodes to the “Stonewall” definition. The soft option of the rigidwall is used, which means that the slave nodes will come to stop within 10 time steps of initial contact with the rigidwall.

Reference:

Schweizerhof, K. and Weimer, K.

List of LS-DYNA input deck:

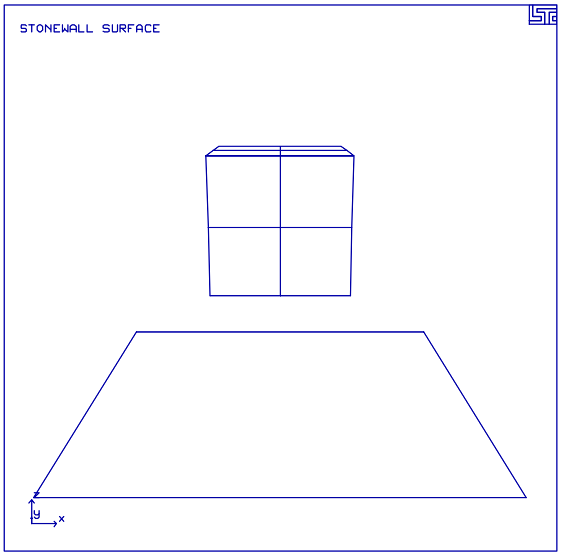
```
*KEYWORD
*TITLE
STONEWALL SURFACE
$
$  LSTC Example
$
$  Last Modified: September 22, 1997
$
$  Units: ton, mm, s, N, MPa, N-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
  .4001E-3
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_HOURGLASS
$      ihq        qh
         4
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
 0.0200E-3
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
  .0010E-3
$
*DATABASE_GLSTAT
$       dt
   4.0e-06
$
*DATABASE_NODOUT
$       dt
   4.0e-06
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
        13       201
$
*DATABASE_RWFORC
$       dt
   4.0e-06
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Rigidwalls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*RIGIDWALL_PLANAR_FORCES
$     nsid    nsidex     boxid
         1         0         0
$
$       xt        yt        zt        xh        yh        zh      fric
      20.0      20.0       0.0      20.0      20.0     100.0     0.000
$
$     soft      ssid      nid1      nid2      nid3      nid4
        10         0         1         4        13        16
$
$
*SET_NODE_LIST
$      sid
         1
$     nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
       201       202       203       204       205       206       207       208
       209
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  All nodes located within box 1 are given an initial velocity.
$
*INITIAL_VELOCITY
$     nsid    nsidex     boxid
                             1
$       vx        vy        vz
       0.0       0.0 -100000.0
$
*DEFINE_BOX
$    boxid       xmm       xmx       ymn       ymx       zmn       zmx
         1      14.9      25.1      14.9      25.1       9.0      21.0
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid    adpopt
wall-display
         1         1         1
cube
         2         2         2         0         0         0
$
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db
         1   2.00e-8  100000.0     0.300
$
*MAT_ELASTIC
```

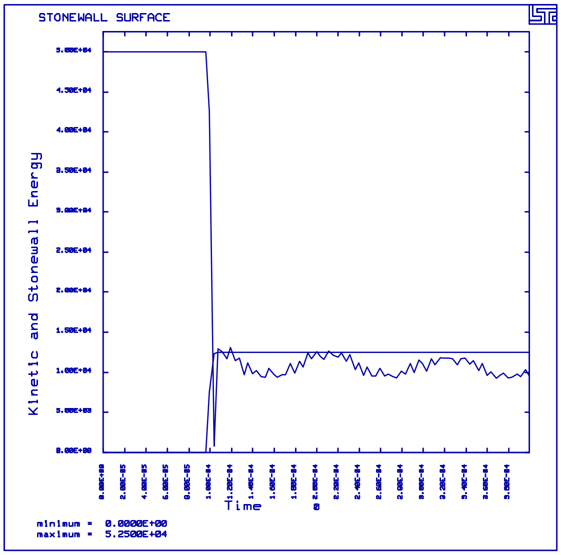
```
$      mid        ro         e        pr        da        db
         2   1.00e-8  100000.0     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1             0.83333       2.0       3.0
$       t1        t2        t3        t4      nloc
       2.0       2.0       2.0       2.0
$
*SECTION_SOLID
$      sid    elform
         2
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1    5.000000E+00    5.000000E+00    0.000000E+00       7       0
       4    3.500000E+01    5.000000E+00    0.000000E+00       7       0
      13    3.500000E+01    3.500000E+01    0.000000E+00       0       0
       .
       ...  in total, 31 nodes defined
       .
     201    1.500000E+01    1.500000E+01    1.000000E+01       0       0
     225    1.500000E+01    2.500000E+01    2.000000E+01       0       0
     226    2.000000E+01    2.500000E+01    2.000000E+01       0       0
     227    2.500000E+01    2.500000E+01    2.000000E+01       0       0
$
$$$$$  Shell Elements - For Display of the Rigidwall
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
       1       1       1       4      13      16
$
$$$$$  Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
     101       2     201     202     205     204     210     211     214     213
     102       2     202     203     206     205     211     212     215     214
     103       2     204     205     208     207     213     214     217     216
     104       2     205     206     209     208     214     215     218     217
     105       2     210     211     214     213     219     220     223     222
     106       2     211     212     215     214     220     221     224     223
     107       2     213     214     217     216     222     223     226     225
     108       2     214     215     218     217     223     224     227     226
$
*END
```

Results:

```
taurus g=d3plot
19
rx -80 view
```



```
phs3 glstat
otxt Kinetic and Stonewall Energy
oset 0 5.25e4 kinetic over stonewall
```



LS-DYNA Manual Section: *RIGIDWALL_PLANAR_MOVING

Additional Sections:

*CONTACT_AUTOMATIC_SINGLE_SURFACE

Example: Symmetric Crush Tube

Filename: rigidwall_planar.symtube.k

Description:

A tube is crushed using a planar, moving rigid wall.

Model:

Because of symmetry , only 1/4 of the system is modeled. Automatic single surface contact is defined to prevent penetrations as the tube folds on itself. The bottom nodes of the tube are fixed using SPC's. The top of the tube is hit by a rigid wall that is defined with a mass of 800 kg and an initial velocity of 8.94 mm/ms in the negative z-direction. The friction coefficient on the wall is 1.0, this means that the nodes are prevented from sliding along the plane of the wall. An extra node is defined and associated with the rigid wall so that the walls velocity and displacement can be tracked in the ascii output file nodout (node id 99999).

Results:

The tubes crush and the wall forces from the ascii output file rwforc are shown. The force-deflection of the crush tube can be obtained by using the force data from rwforc and the displacement data from nodout.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Symmetric Short Crush Tube Impacted by a Moving Wall
$
$  LSTC Example
$
$  Last Modified: October 10, 1997
$
$ Symmetric model - 1/4 of the tube
$   - Remove corner elements on desired initial crush area (2 shells)
$       shells commented out: 409, 410
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     15.01         0       0.0       0.0       0.0
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       1.0
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
       0.1
$
*DATABASE_MATSUM
$       dt
       0.1
$
*DATABASE_NODOUT
$       dt
       0.1
```

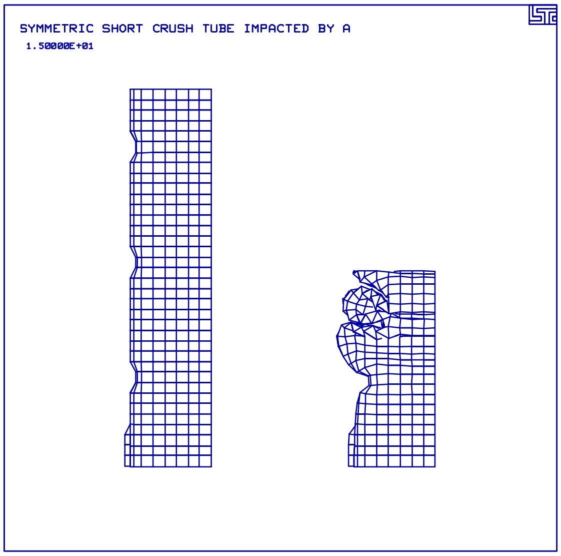
```
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
     99999       414       486
$
*DATABASE_RWFORC
$       dt
       0.1
$
*DATABASE_SLEOUT
$       dt
       0.1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         0
$  Equating ssid to zero means that all segments are included in the contact
$
$       fs        fd        dc        vc       vdc    penchk        bt        dt
      0.08      0.08
$
$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Rigidwalls
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*RIGIDWALL_PLANAR_MOVING_FORCES
$     nsid    nsidex     boxid
         0         0         0
$
$       xt        yt        zt        xh        yh        zh      fric
       0.0       0.0     274.0       0.0       0.0       0.0       1.0
$
$  sw mass    sw vel
   800.000   8.94000
$
$     soft      ssid     node1     node2     node3     node4
         0         0     99999
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
```

```
$      pid       sid       mid     eosid      hgid      grav    adpopt
corner1
         1         1         1
$
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 7.830E-06     200.0       0.3     0.207               0.750
$
$        c         p      lcss      lcsr
        40         5
$  PLASTIC STRESS/STRAIN CURVES
$     eps1      eps2      eps3      eps4      eps5      eps6      eps7      eps8
     0.000     0.080     0.160     0.400     0.750
$      es1       es2       es3       es4       es5       es6       es7       es8
     0.207     0.250     0.275     0.290     0.300
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         2              3.0000
$       t1        t2        t3        t4      nloc
      2.00      2.00      2.00      2.00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Constraints and Boundary
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$ Nodal single point constraints (SPC's)
$   - fix on bottom of tube
$   - symmetry along both sides of tube
$
*BOUNDARY_SPC_NODE
$      nid cid x y z rx ry rz
         1,  0,1,1,1, 1, 1, 1
         2,  0,1,1,1, 1, 1, 1
       .
       ...  in total, 86 SPC's defined
       .
       252,  0,1,0,0, 0, 1, 1
       259,  0,1,0,0, 0, 1, 1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
   99999             0.0             0.0           274.0       0       0
       1 -5.00000000E+01 -4.80000000E+01 0.000000000E+00       0       0
       2 -4.16667000E+01 -4.80000000E+01 0.000000000E+00       0       0
       .
       ...  in total, 519 nodes defined
       .
```

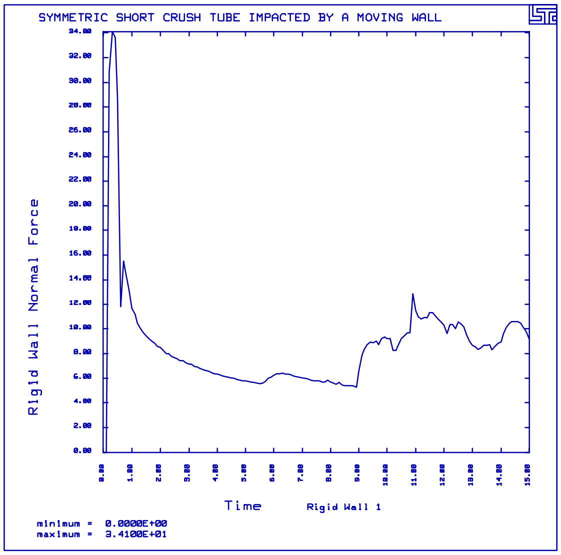
```
     715 -5.80000000E+01 -2.40000000E+01 2.724830000E+02       0       0
     716 -5.80000000E+01 -3.20000000E+01 2.724830000E+02       0       0
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
     752       1     547     552     553     553
     753       1     553     548     547     547
       1       1       1       2       9       8
       2       1       2       3      10       9
       .
       ...  in total, 467 shells defined
       .
     640       1     710     711     716     715
     641       1     711     485     487     716
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90 xtrans -80 view
xtrans 160 state 16 over view
```



```
phs3
rwforc
oscl -1 normal
```



LS-DYNA Manual Section: *SECTION_SHELL

Additional Sections:

*CONSTRAINED_SPOTWELD
*LOAD_NODE_POINT

Example: Fuse Plate in Tension Exhibits Hourglassing

Filename: section_shell.hourglassing.k

Description:

A fuse plate is used to connect a cut in a wide flange beam. The beam is loaded at an end, putting the fuse plate in tension. In this loading condition, the fuse plate exhibits a great deal of hourglassing.

Model:

The fuse plate and beam are constructed with shell elements and a piecewise linear plasticity material model with failure. The fuse plate is connected to the beam using spot welds (*CONSTRAINED_SPOTWELD). One end of the beam is fixed with SPC's, while the other end has several nodal point loads (*BOUNDARY_SPC_NODE, *LOAD_NODE_POINT). Multiple point loads are used to better distribute the input loads.

Results:

One look at the figures explains why it's called "hourglassing". To fix the hourglassing problem the fuse plate could be re-meshed or a fully integrated shell element formulation could be used.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
Fuse plate being pulled a part exhibits hourglassing troubles.
$
$  LSTC Example
$
$  Last Modified: October 14, 1997
$
$  Really good hourglassing on fuse plate - part 3
$
$  Switch to shell formulation S/R Hughes-Liu (6) - eliminates HG
$     ===> *SECTION_SHELL - ELFORM
$
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
     10.01
$
*CONTROL_ENERGY
$     HGEN      RWEN    SLNTEN     RYLEN
         2         2         1         1
$
*CONTROL_OUTPUT
$    NPOPT    NEECHO    NREFUP    IACCOP     OPIFS    IPNINT    IKEDIT
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       1.0
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
       0.1
$
*DATABASE_MATSUM
$       dt
       0.1
$
*DATABASE_SWFORC
$       dt
       0.1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Constrain the Plates Together
```

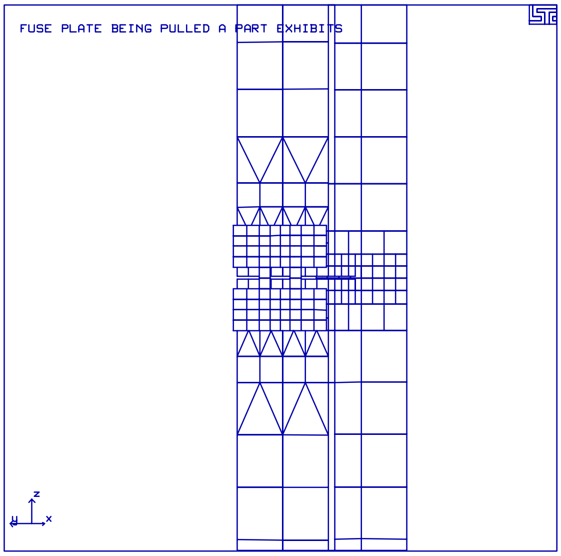
```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$  Spotweld the fuse plate to the post flanges.
$
*CONSTRAINED_SPOTWELD
$       n1        n2        sn        sf         n         m
       284       511
       247       512
       428       527
       417       517
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Boundary and Loading Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*BOUNDARY_SPC_NODE
$      nid       cid         x         y         z        rx        ry        rz
       150         0         1         1         1         1         1         1
       151         0         1         1         1         1         1         1
       152         0         1         1         1         1         1         1
       179         0         1         1         1         1         1         1
       180         0         1         1         1         1         1         1
       181         0         1         1         1         1         1         1
       204         0         1         1         1         1         1         1
       205         0         1         1         1         1         1         1
$
*LOAD_NODE_POINT
$      nid       dof      lcid        sf       cid        m1        m2        m3
        17         1         2 2.000E+03         0
        18         1         2 2.000E+03         0
        19         1         2 2.000E+03         0
        61         1         2 2.000E+03         0
        62         1         2 2.000E+03         0
        63         1         2 2.000E+03         0
       100         1         2 2.000E+03         0
       101         1         2 2.000E+03         0
$
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
         2
$           abscissa            ordinate
0.00000000000000E+00 1.0000000000000E+00
1.00000000000000E+04 1.0000000000000E+04
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
pstflang
```

```
         1         1         1
postweb
         2         2         1
fuseplat
         3         3         1
$
$
$$$$  Materials
$
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         1 0.783E-05 2.000E+02       0.3 2.070E-01           7.500E-01
$  Cowper/Symonds Strain Rate Parameters
$        c         p      lcss      lcsr
        40         5
$  Plastic stress/strain curve
 0.000E+00 8.000E-02 1.600E-01 4.000E-01 9.900E+01
 2.070E-01 2.500E-01 2.750E-01 2.899E-01 3.000E-01
$
$
$$$$  Sections
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         1         6
$       t1        t2        t3        t4      nloc
5.4600E+00 5.460E+00 5.460E+00 5.460E+00
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         2         6
$       t1        t2        t3        t4      nloc
4.3200E+00 4.320E+00 4.320E+00 4.320E+00
$
$
*SECTION_SHELL
$      sid    elform      shrf       nip     propt   qr/irid     icomp
         3         2
$         3         6
$       t1        t2        t3        t4      nloc
4.7625E+00 4.762E+00 4.762E+00 4.762E+00
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$   node               x               y               z      tc      rc
       1 0.000000000E+00 7.500000000E+01 2.337080000E+03       0       0
       2 8.750000000E+01 5.000000000E+01 2.360630000E+03       0       0
       .
       ...  in total, 522 nodes defined
       .
     675 0.000000000E+00 2.500000000E+01 2.286845000E+03       0       0
     676 0.000000000E+00 7.500000000E+01 2.286845000E+03       0       0
$
```

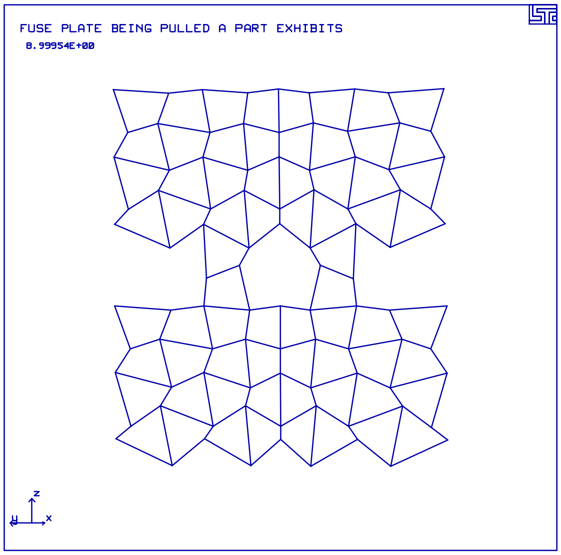
```
$$$$$$$$  Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
     487       1     647     123     501     501
     488       1     647     501     653     653
       .
       ...  in total, 436 shells defined
       .
     387       3     499     496     289     497
     388       3     422     499     497     287
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90 ry 60 m 3 center
zmax 50000 dist 30000 dam view
```



```
s 10
m 3
center view
```



LS-DYNA Manual Section: *SECTION_SOLID

Additional Sections:

*CONTACT_ERODING_SINGLE_SURFACE
*INITIAL_VELOCITY_GENERATION

Example: Breaking Post Exhibits Hourglassing

Filename: section_solid.hourglassing.k

Description:

A rigid beam strikes a post near the top of the post. There is hole cut out of the lower portion of the post to reduce its' section modulus and thus, allow it to snap-off easier. In the first model, the post begins to break, but hourglassing starts to dominate the solution and the post does not completely snap.

In the second model, a fully integrated solid formulation is used for the post, causing the post to snap-off as desired.

Model:

The beam is constructed with rigid shell elements. An initial velocity is given to the beam using the *INITIAL_VELOCITY_GENERATION keyword. The post is constructed with solid elements using a piecewise linear plasticity material model with failure. Single point constraints (SPC's) are placed on the bottom of the post. Eroding single surface contact is required in order for the contact to behave properly while the post snaps in two (*CONTACT_ERODING_SINGLE_SURFACE).

Results:

The first model results are significantly different than the second model due to hourglassing.

List of LS-DYNA input deck:

```
*KEYWORD
*TITLE
A post with a hole is hit by a beam and is supposed to snap at the hole.
$
$  LSTC Example
$
$  Last Modified: October 15, 1997
$
$$  This model uses constant stress solid element formulation (default: type 1)
$$  for the posts and default hourglass viscosity type 1.  This formulation
$$  results in considerable hourglassing and incomplete failure of the post.
$
$   By switching the solid element formulation to fully integrated S/R (type 2)
$   results are much cleaner.
$
$  Units: mm, kg, ms, kN, GPa, kN-mm
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Control Ouput
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$   endtim    endcyc     dtmin    endneg    endmas
      5.00
$
*CONTROL_ENERGY
$     hgen      rwen    slnten     rylen
         2         2
$
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop     opifs    ipnint    ikedit
         1         3
$
$
*DATABASE_BINARY_D3PLOT
$       dt      lcdt
       0.5
$
*DATABASE_EXTENT_BINARY
$    neiph     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg

$   cmpflg    ieverp    beamip
                   1
$
*DATABASE_BINARY_D3THDT
$       dt      lcdt
    999999
$
*DATABASE_GLSTAT
$       dt
      0.10
$
*DATABASE_MATSUM
$       dt
      0.10
$

*DATABASE_NODOUT
```

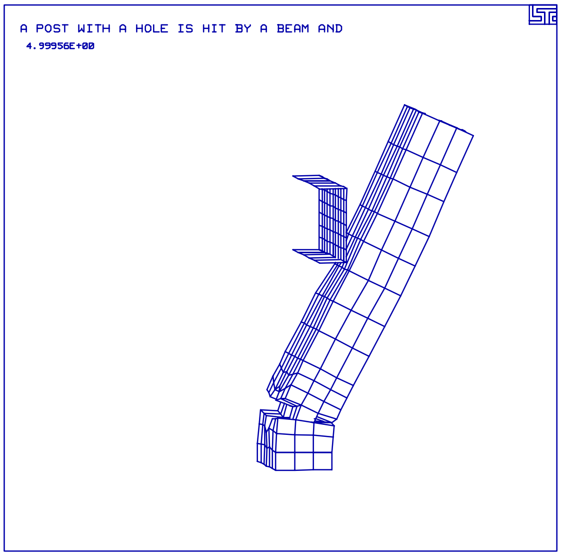
```
$       dt
      0.10
$
*DATABASE_HISTORY_NODE
$      id1       id2       id3       id4       id5       id6       id7       id8
       758
$
*DATABASE_RBDOUT
$       dt
      0.10
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Contacts - Sliding Interfaces
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*CONTACT_ERODING_SINGLE_SURFACE
$     ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         0
$       fs        fd        dc        vc       vdc    penchk        bt        dt

$      sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf

$     isym    erosop      iadj
                   1         1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Initial and Boundary Conditions
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$$  The beam (part 3) is given an initial velocity towards the post.
$
*INITIAL_VELOCITY_GENERATION
$      sid      styp     omega        vx        vy        vz
         3         2                27.8       0.0       0.0
$       xc        yc        zc        nx        ny        nz     phase

$
$$$$  Fix the bottom nodes of the post.
$
*BOUNDARY_SPC_NODE
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      nid cid x y z rx ry rz
       163,  0,1,1,1, 1, 1, 1
       166,  0,1,1,1, 1, 1, 1
       .
       ...  in total, 28 SPC's defined
       .
       645,  0,1,1,1, 1, 1, 1
       648,  0,1,1,1, 1, 1, 1
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Parts and Materials
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

$
```

```
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$$$ Part    3    shell: beam
$
$$$ Part    4    solid: lower_post
$
$$$ Part    5    solid: upper_post
$
$
*PART
$      pid       sid       mid     eosid      hgid      grav    adpopt
bumper
         3         1         1
lower_post
         4         2         2
upper_post
         5         2         3
$
$
$$$$   Materials
$
$$  Bumper - Rigid, constrained to translate only in the x-direction
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
         1 0.143E-02     200.0      0.33
$
$      cmo      con1      con2
       1.0         5         7
$
$   lco/a1        a2        a3        v1        v2        v3

$
$
$$  Post - the lower portion is softer and fails sooner than the upper portion
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         2 0.499E-06     11.37      0.32    0.0468                0.11
$
$        c         p      lcss      lcsr

$  Plastic stress/strain curve
    0.0000    0.2500
    0.0468    0.0470
$
$
*MAT_PIECEWISE_LINEAR_PLASTICITY
$      mid        ro         e        pr      sigy      etan      eppf      tdel
         3 0.499E-06    110.37      0.32    0.0468                0.25
$
$        c         p      lcss      lcsr

$  Plastic stress/strain curve
    0.0000    0.2500
    0.0468    0.0470
$
$
$$$$   Sections
$
*SECTION_SHELL

$      sid    elform      shrf       nip     propt   qr/irid     icomp
```

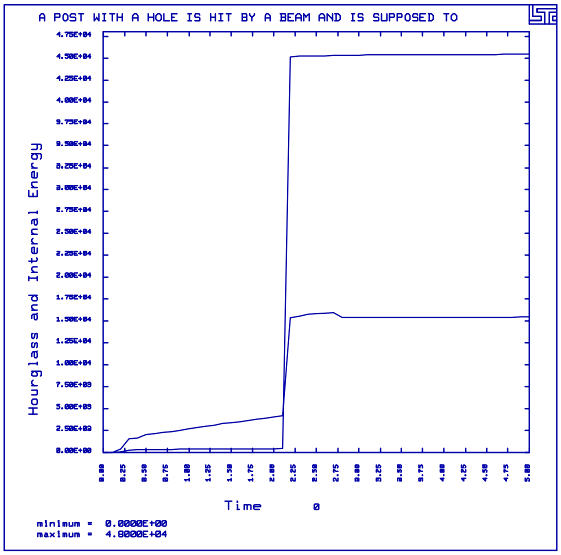
```
         1         2                 3.0
$       t1        t2        t3        t4      nloc
      1.54      1.54      1.54      1.54
$
$
*SECTION_SOLID
$      sid    elform
         2         1
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$  Define Nodes and Elements
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*NODE
$    nid               x               y               z      tc      rc
      32 -1.23794000E+02 1.200000000E+03 3.910000000E+02       0       0
      33 -1.23794000E+02 1.257150000E+03 3.910000000E+02       0       0
       .
       ...  in total, 529 nodes defined
       .
     764 -7.37940000E+01 1.400030000E+03 5.068340000E+02       0       0
     765 -7.37940000E+01 1.457180000E+03 5.068340000E+02       0       0
$
$$$$$$$$$    Solid Elements
$
*ELEMENT_SOLID
$    eid     pid      n1      n2      n3      n4      n5      n6      n7      n8
       1       4     163     172     175     166     164     173     176     167
       2       4     172     181     184     175     173     182     185     176
       .
       ...  in total, 252 solids defined
       .
     333       5     389     639     705     489     390     640     706     490
     335       5     489     705     707     491     490     706     708     492
$
$$$$$$$$$    Shell Elements
$
*ELEMENT_SHELL
$    eid     pid      n1      n2      n3      n4
     355       3      32      48      49      33
     356       3      33      49      50      34
       .
       ...  in total, 70 shells defined
       .
     507       3     765     734      85     732
     508       3     733     765     732      84
$
$
*END
```

Results:

```
taurus g=d3plot
angle 1 rx -90 state 11
ry 10 rx 5 view
```

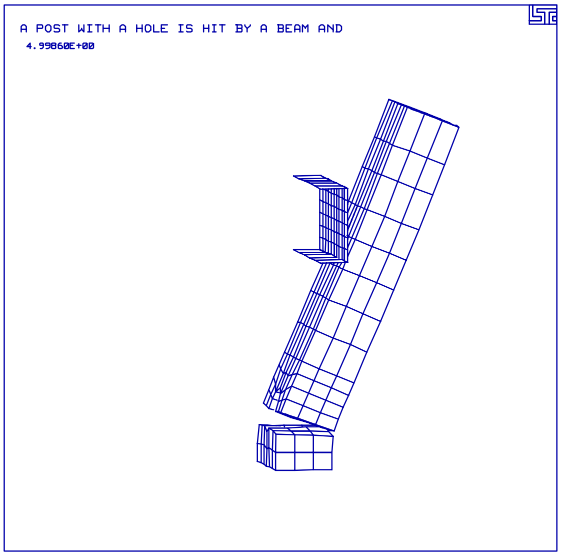


```
phs3 glstat
otxt Hourglass and Internal Energy
oset 0 4.8e4 hour over internal
```

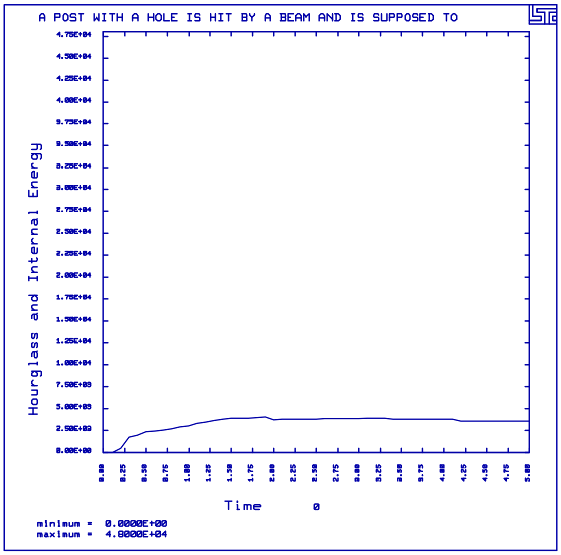


Results - No Hourglassing:

```
taurus g=d3plot
angle 1 rx -90 state 11
ry 10 rx 5 view
```



```
phs3 glstat
otxt Hourglass and Internal Energy
oset 0 4.8e4 hour over internal
```



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ACKNOWLEDGMENTS

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