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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.
Airbag Deploys into Cylinder

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).
*AIRBAG_SIMPLE_AIRBAG_MODEL
Airbag Deploys into Cylinder

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 Output
$  
$  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
$  neigh  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 p sca 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 dal 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 ytzt xh yhzh fric
0.0 0.0 0.0 0.0 1.0 0.0 0.5

$
*AIRBAG_SIMPLE_AIRBAG_MODEL
Airbag Deploys into Cylinder

$\text{Define Contacts - Sliding Interfaces}$

$\text{Contact between the airbag and the cylinder.}$

$\text{Define Parts and Materials}$

$\text{Materials}$

$\text{MAT_RIGID}$

$\text{MAT_RIGID}$
$ *AIRBAG_SIMPLE_AIRBAG_MODEL
Airbag Deploys into Cylinder

$ 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
$ ao

$ 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
$ tl 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
$ tl t2 t3 t4 nloc
0.015 0.015 0.015 0.015
$ bl b2 b3 b4 b5 b6 b7 b8


$$$$$$$ Define Nodes and Elements
$ *
$ in total, 3867 nodes defined
$ nid x y z tc rc
*NODE
3722 2.2500000000E+00 2.5000000000E+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 1.2000000000E+01 0.0000000000E+00 -1.17000000E+01
7587 -1.2000000000E+01 0.0000000000E+00 -1.30000000E+01
7588 1.2000000000E+01 0.0000000000E+00 -1.30000000E+01

$$$$$$ Elements
$ *
*ELEMENT_SHELL
$ eid pid n1 n2 n3 n4
### Airbag Deploys into Cylinder

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>7547</th>
<th>7509</th>
<th>7148</th>
<th>7549</th>
</tr>
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<tbody>
<tr>
<td>6993</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6994</td>
<td>1</td>
<td>7509</td>
<td>7510</td>
<td>7149</td>
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<tr>
<td>6995</td>
<td>1</td>
<td>7510</td>
<td>7511</td>
<td>7150</td>
<td>7149</td>
</tr>
</tbody>
</table>

... in total, 3792 shells defined.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>7078</th>
<th>7048</th>
<th>7144</th>
<th>7145</th>
</tr>
</thead>
<tbody>
<tr>
<td>6990</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6991</td>
<td>3</td>
<td>7108</td>
<td>7078</td>
<td>7145</td>
<td>7146</td>
</tr>
<tr>
<td>6992</td>
<td>3</td>
<td>5998</td>
<td>7108</td>
<td>7146</td>
<td>7147</td>
</tr>
</tbody>
</table>

$\ast END$
Results:

```plaintext
taurus g=d3plot
19
state 15 rx 20 view
```

```plaintext
phs3
abstat
grid oset 0
180 pressure
```
*AIRBAG_SIMPLE_AIRBAG_MODEL*

Airbag Deploys into Cylinder
**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/mm² 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
*BOUNDARY_PRESCRIBED_MOTION
Blow Molding

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  mslst
  .000  .400  0
$
$ *CONTROL_BULK_VISCOSITY
$  Q2  Q1
  1.500  .060
$
$ *CONTROL_CONTACT
$  slsfac  rwpnal  islchk  shlthk  penopt  thkchg  orien
    .100  2
$  usrsstr  usrfrc  nabcsc  interm  xpene  ssthk  ecdt  tiedprj
    0  10  0  4.000
$
$ *CONTROL_DYNAMIC_RELAXATION
$  nrcyck  dtrol  drfcrt  drterm  tssfdr  irelal  edttl  idrflg
  250  .001  .995
$
$ *CONTROL_ENERGY
$  hgen  rwen  slnten  rlyen
    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*

<table>
<thead>
<tr>
<th>neip</th>
<th>neips</th>
<th>maxint</th>
<th>strflg</th>
<th>sigflg</th>
<th>epsflg</th>
<th>rltflg</th>
<th>engflg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cmpflg</th>
<th>ieverp</th>
<th>beamip</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### *DATABASE_GLSTAT*

<table>
<thead>
<tr>
<th>dt</th>
</tr>
</thead>
<tbody>
<tr>
<td>.100E-03</td>
</tr>
</tbody>
</table>

#### Define Contacts - Sliding Interfaces

- **Contact Surface to Surface**
  - **cid**: 3, Name: IF1
  - **ssid**: 3, **msid**: 2, **sstyp**: 3, **mstyp**: 3, **sboxid**: 0, **mboxid**: 0, **spr**: 0, **mpr**: 0
  - **fs**: 0.000E+00, **fd**: 0.000E+00, **dc**: 0.000E+00, **vc**: 0.000E+00, **vdc**: 0.000E+00, **penchk**: 0, **bt**: 0.000E+00, **dt**: 1.000E+20
  - **sfs**: .100E+01, **sfm**: .100E+01, **sst**: .098E+01, **mst**: .098E+01, **sfst**: .100E+01, **sfmt**: .100E+01
  - **fsf**: .100E+01, **vsf**: .100E+01

- **cid**: 4, Name: IF4
  - **ssid**: 1, **msid**: 3, **sstyp**: 3, **mstyp**: 3, **sboxid**: 0, **mboxid**: 0, **spr**: 0, **mpr**: 0
  - **fs**: 0.000E+00, **fd**: 0.000E+00, **dc**: 0.000E+00, **vc**: 0.000E+00, **vdc**: 0.000E+00, **penchk**: 0, **bt**: 0.000E+00, **dt**: 1.000E+20
  - **sfs**: .100E+01, **sfm**: .100E+01, **sst**: .095E+01, **mst**: .095E+01, **sfst**: .100E+01, **sfmt**: .100E+01
  - **fsf**: .100E+01, **vsf**: .100E+01

- **cid**: 5, Name: IF5
  - **ssid**: 3, **msid**: 0, **sstyp**: 3, **mstyp**: 0, **sboxid**: 0, **mboxid**: 0, **spr**: 0, **mpr**: 0
  - **fs**: 0.000E+00, **fd**: 0.000E+00, **dc**: 0.000E+00, **vc**: 0.000E+00, **vdc**: 0.000E+00, **penchk**: 0, **bt**: 0.000E+00, **dt**: 1.000E+20
  - **sfs**: .100E+01, **sfm**: .100E+01, **sst**: .100E+01, **mst**: .100E+01, **sfst**: .100E+01, **sfmt**: .100E+01
  - **fsf**: .100E+01, **vsf**: .100E+01

### Define Parts and Materials
*BOUNDARY_PRESCRIBED_MOTION
Blow Molding

*****************************************************************************
$...>....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
$1co 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
$1co 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
0.000E+00 0.000E+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
$

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  $$$$$$ Define Boundary Conditions
$  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*BOUNDARY_PRESCRIBED_MOTION
Blow Molding

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
$*BOUNDARY_PRESCRIBED_MOTION_RIGID$
$     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  .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$
$     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$
$     1  40.000  3018  3019  3650  3649$
$     1  40.000  3019  3620  3651  3650$

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$  Define Nodes and Elements
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
**BOUNDARY_PRESCRIBED_MOTION**

Blow Molding

```
*NODE
$    nid               x               y               z      tc      rc
1001  .130103000E+02 -.113825400E+01  .535000000E+02
1002  .129937800E+02  .126376400E+01  .535000000E+02
...
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
...
2197       2    2226    2187    2198    2227
2198       2    2227    2198    2209    2228
$  
*END
```
Results:

\begin{verbatim}
  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
\end{verbatim}
*BOUNDARY_PRESCRIBED_MOTION
Blow Molding
Two Plates Connected With Butt Welds

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 : x1-force = 5.56053E+00
: y1-force = 2.28915E-03 : z1-force = -1.93680E-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 : x1-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
Two Plates Connected With Butt Welds

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 itrst irnxx istupd theory bwc miter
       1 6
$
$   *
$   *DATABASE_BINARY_D3PLOT
$   dt lcdn
       0.2
$
$   *DATABASE_EXTENT_BINARY
$   neiph neips maxint strflg sigflg epsflg rltflg engflg
$
$   cmpflg ieverp beamip
       1
$
$   *DATABASE_BINARY_D3THDT
$   dt lcdn
       999999
$
$   *DATABASE_GLSTAT
$   dt
       0.1
$
$   *DATABASE_MATSUM
$   dt
       0.1
$
$   *DATABASE_NODOUT
$   dt
Two Plates Connected With Butt Welds

0.1

*DATABASE_HISTORY_NODE
$ id1   id2   id3   id4
22  23  35  36
$

*DATABASE_SECFORC
$ dt
0.010
$

*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
$

*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
$

*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
*CONSTRAINED_GENERALIZED_WELD
Two Plates Connected With Butt Welds

$  
*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
$  
$  
$**$  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
Two Plates Connected With Butt Welds

*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
$

*PART

$ pid  sid  mid  eosid  hgid  grav  adpopt
plate1  2  2  1
plate2  3  2  1
$

*MAT_PLASTIC_KINEMATIC

$ mid   ro   e   pr   sigy   etan  beta
  1   2.70e-6   68.9   0.330   0.286   0.00689
$

*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
$

*NODE

$ nid  x   y   z   tc   rc
### *CONSTRAINEDGENERALIZED_WELD*

Two Plates Connected With Butt Welds

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>20</td>
<td>14</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>14</td>
<td>15</td>
<td>9</td>
<td>8</td>
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</table>

... in total, 40 nodes defined

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>4</td>
<td>0.000000000E+01</td>
<td>0.000000000E+00</td>
<td>0.000000000E+00</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>0.000000000E+01</td>
<td>0.000000000E+00</td>
<td>0.000000000E+00</td>
<td></td>
</tr>
</tbody>
</table>

$^

### $$$$$$$ Shell Elements$

$^

**ELEMENT_SHELL**

$^

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>20</td>
<td>14</td>
<td>8</td>
<td>22</td>
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<td>2</td>
<td>14</td>
<td>15</td>
<td>9</td>
<td>8</td>
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</tbody>
</table>

... in total, 24 shells defined

<table>
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<tr>
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<th>pid</th>
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<th>n2</th>
<th>n3</th>
<th>n4</th>
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<td>3</td>
<td>5</td>
<td>6</td>
<td>32</td>
<td>31</td>
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<tr>
<td>24</td>
<td>3</td>
<td>6</td>
<td>38</td>
<td>40</td>
<td>32</td>
</tr>
</tbody>
</table>

$^

**END**
Results:

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

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

Two Plates Connected With Butt Welds
**CONSTRAINED_JOINT_PLANAR**

Sliding Blocks with Planar Joint

**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 × 2 × 2 slides along a second block measuring 2 × 2 × 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.
*CONSTRAINED_JOINT_PLANAR
Sliding Blocks with Planar Joint

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

$  Define Planar Joint
$  
$  Define nodes that output into nodout
$  
$  Define Planar Joint
$  
$$$$  Define Planar Joint
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
$*$CONSTRAINED_JOINT_PLANAR$ $
$$
  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 $$$
$$
$*$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
-----------------------------------------
29
*CONSTRAINED_JOINT_PLANAR

Sliding Blocks with Planar Joint

$ 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$
$
$ $$$ Pressure load on top of block$
$
$ *LOAD_SEGMENT$
$
$ lcid sf at n1 n2 n3 n4
  1 1.000E+00 0.000E+00 97 106 107 98
  1 1.000E+00 0.000E+00 106 115 116 107
  1 1.000E+00 0.000E+00 98 107 108 99
  1 1.000E+00 0.000E+00 107 116 117 108$
$
$ *DEFINE_CURVE$
$
$ lcid sidr scla sclo offa offo
  1 0 0.000E+00 0.000E+00 0.000E+00 0.000E+00$
$
$ abscissa ordinate
  0.00000000E+00 0.00000000E+00
  9.999999978E-03 1.00000000E+02
  1.99999996E-02 1.00000000E+02$
$
$ $$$ Force load on lower edge of block$
$
$ *LOAD_NODE_POINT
## Sliding Blocks with Planar Joint

### CONSTRAINTED_JOINT_PLANAR

<table>
<thead>
<tr>
<th>nid</th>
<th>dof</th>
<th>lcid</th>
<th>sf</th>
<th>cid</th>
<th>ml</th>
<th>m2</th>
<th>m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>91</td>
<td>3</td>
<td>2-1.000E+00</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
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<td>2-1.000E+00</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td>93</td>
<td>3</td>
<td>2-1.000E+00</td>
<td>0</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*DEFINE_CURVE*

<table>
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<tr>
<th>lcid</th>
<th>sidr</th>
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<th>sclo</th>
<th>offa</th>
<th>offo</th>
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<td>2</td>
<td>0</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
</tbody>
</table>

abscissa | ordinate
---------|---------
0.00000000E+00 | 0.00000000E+00
1.99999996E-02 | 4.00000000E+01

**Initial Conditions**

**Nodes on sliding block**

<table>
<thead>
<tr>
<th>nid</th>
<th>vx</th>
<th>vy</th>
<th>vz</th>
<th>vxe</th>
<th>vye</th>
<th>vze</th>
</tr>
</thead>
<tbody>
<tr>
<td>91</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>92</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>93</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>94</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>95</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
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<td>4.000E+02</td>
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<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>97</td>
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<td>0.000E+00</td>
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<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>98</td>
<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
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<tr>
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</tr>
<tr>
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<tr>
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<tr>
<td>104</td>
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<tr>
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<td>4.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
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<td>0.000E+00</td>
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<td>0.000E+00</td>
<td>0.000E+00</td>
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**Extra nodes on sliding rigid block**

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<th>nid</th>
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<th>vy</th>
<th>vz</th>
<th>vxe</th>
<th>vye</th>
<th>vze</th>
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<td>0.000E+00</td>
<td>0.000E+00</td>
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<td>0.000E+00</td>
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<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td></td>
</tr>
</tbody>
</table>
*CONSTRAINED_JOINT_PLANAR
Sliding Blocks with Planar Joint

$$$$  Nodes and Elements
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$
*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
*CONSTRAINED_JOINT_PLANAR
Sliding Blocks with Planar Joint
**CONSTRANGED_JOINT_REVOLUTE**

Hinged Shell with Stop Angle (Revolute Joint)

**LS-DYNA Manual Section:**  *CONSTRANGED_JOINT_REVOLUTE*

**Additional Sections:**

*CONSTRANGED_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 *CONSTRANGED_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.
*CONSTRAINED_JOINT_REVOLUTE
Hinged Shell with Stop Angle (Revolute Joint)

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  mslst
$  $$  5
$  $$  *DEFINE_CURVE
$  $$  lcid  sidr  scla  sclo  offa  offo
$  $$  5
$  $$  absissa  ordinate
$  $$  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_REBOUT
$  dt  0.0001
$

Hinged Shell with Stop Angle (Revolute Joint)

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.

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 further 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.

*CONSTRAINED_JOINT_STIFFNESS_GENERALIZED
$  jsid  pidA  pidB  cidA  cidB
  1  1  2  5  5
$
$  1cidPH  1cidT  1cidPS  dlcidPH  dlcidT  dlcidPS
$
$  esPH  fmPS  esT  fmT  esPS  fmPS
  100.0  10.0  10.0
$
$  nsaPH  psaPH  30.0  nsaT  psaT  nsaPS  psaPS
$
$
*DEFINECOORDINATE_NODES
$  cid  n1  n2  n3
$

37
Hinged Shell with Stop Angle (Revolute Joint)

5 1 2 3

*LOAD_NODE_POINT

3         3         1         1.000E+00
4         3         1         1.000E+00

*DEFINE_CURVE

1

0.00000000E+00 1.00000000E+00
1.00000000E+00 1.00000000E+00

*PART

1         1         1         0
2         1         2         0

*MAT_RIGID

1 7.000E-04 3.000E+07 3.000E-01
2 7.000E-04 3.000E+07 3.000E-01

1.0         7         7

$
*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
$

$...>....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
$

*ELEMENT_SHELL
$ eid     pid      n1      n2      n3      n4
  1      1       1       3       4       2
  3      2       7       9      10       8
$

*END
Results:

```plaintext
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
```

```plaintext
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 $40 \times 40 \times 2$ 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.
*CONSTRAINED_LINEAR
Linearly Constrained Plate

List of LS-DYNA input deck:

*KEYWORD
*TITLE
Linear Constraint Equations
$ $ LSTC Example
$ $ Last Modified: September 3, 1997
$ $ Units: mm, s
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$ $$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$$ $*CONTROL_TERMINATION
$ $ endtim $endcyc $dtmin $endneg $endmas
0.0005
$ $*CONTROL_CONTACT
$ $ slsfac $rwpnal $islchk $shlthk $penopt $thkchg $orien
0.1 2
$ $ usrstr $usrfac $nsbcs $intem $xpenen
$ $*CONTROL_HOURGLASS
$ $ ihq $qh
4
$ $*CONTROL_SHELL
$ $ wrpang $itrst $irnxx $istupd $theory $bwc $miter
1
$ $*DATABASE_BINARY_D3PLOT
$ $ dt $lcdt
0.00002
$ $*DATABASE_BINARY_D3THDT
$ $ dt $lcdt
0.00001
$ $*DATABASE_EXTENT_BINARY
$ $ neiph $neips $maxint $strflg $sigflg $epsflg $rltflg $engflg
1
$ $ cmpflg $ieverp $beamip
$ $*$DATABASE_HISTORY_NODE
$ $ id1 $id2 $id3 $id4 $id5 $id6 $id7 $id8
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ 40 41 42
$ $*DATABASE_NODOUT
$ \ dt
0.00001$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$  Constraints and Boundary Conditions
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$$
$$$ nodes 40 and 42 are constrained to have identical z-direction motion $$
*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
*CONSTRAINED_LINEAR
Linearly Constrained Plate

2.0 2.0 2.0 2.0

Define Nodes and Elements

z-translational constraints are placed on several nodes

*NODE

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<tr>
<th>nid</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
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<td>0.000000E+00</td>
<td>3</td>
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</tr>
<tr>
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<td>0.000000E+00</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
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<td>0.000000E+00</td>
<td>0.000000E+00</td>
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<td>0</td>
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<td>4.000000E+01</td>
<td>0.000000E+00</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
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<td>4.000000E+01</td>
<td>0.000000E+00</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
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<td>4.000000E+01</td>
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*ELEMENT_SHELL

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<th>n3</th>
<th>n4</th>
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<td>10</td>
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<tr>
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<td>1</td>
<td>71</td>
<td>72</td>
<td>81</td>
<td>80</td>
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</table>

*END
Results:

- taurus g=d3plot
- 19
- time 5e-4 rx -20 ndplt
- phs3
- nodout
- z-disp
*CONSTRAINED_LINEAR
Linearly Constrained Plate
**CONstrained_Shell_to_Solid**

Impulsively Loaded Cap with Shells and Solids

**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 group 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
Impulsively Loaded Cap with Shells and Solids

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      lcdn
     0.00001
$  *DATABASE_BINARY_D3THDT
$    dt      lcdn
     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
**CONSTRAINED_SHELL_TO_SOLID**

Impulsively Loaded Cap with Shells and Solids

```
DATABASE_HISTORY_NODE
id1  id2  id3  id4  id5  id6  id7  id8
  1   116   284   361   326   326

$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

$ Constraints
$...>.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
```

*CONSTRANDED_SHELL_TO_SOLID*

```
*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
```
*CONSTRAINED_SHELL_TO_SOLID
Impulsively Loaded Cap with Shells and Solids

$ *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_CURVE
$   lcid  sidr  scla  sclo  offa  offo
  1
$

$ *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
$

$ *DEFINE_CURVE
$   lcid  sidr  scla  sclo  offa  offo
  1
$

$ DEFINE_PARTS
$ *DEFINITION
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$

$ DEFINE_MATERIALS
$ *DEFINITION
$...>....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
*
$ Nodes
*
*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
$

$ 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 1 6 8 4 26 29 31 27
 3 1 6 13 12 8 29 36 35 31
...

... in total, 204 solids defined
```
**CONSTRAINED_SHELL_TO_SOLID**
Impulsively Loaded Cap with Shells and Solids

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

\$
\text{Elements - Shells}
\$

*ELEMENT_SHELL

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>326</td>
<td>333</td>
<td>334</td>
<td>327</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>327</td>
<td>334</td>
<td>335</td>
<td>328</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>328</td>
<td>335</td>
<td>336</td>
<td>329</td>
</tr>
</tbody>
</table>

... 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:

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

---

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

---

```plaintext
EXAMPLE OF SHELL BRICK INTERFACES
0.7020E-06
```

---

```plaintext
EXAMPLE OF SHELL BRICK INTERFACES
```

---
*CONSTRAINED_SHELL_TO_SOLID*
Impulsively Loaded Cap with Shells and Solids
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 spotwelds reach the defined failure condition.

Model:

The two plates measure 80 × 40 × 1 mm³ 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).
*CONSTRANGED_SPOTWELD
Spot Weld Secures Two Plates

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 lstd 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
$LSTC Example

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$  Control Ouput
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$  *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      lcmdt
          0.2
$  *DATABASE_BINARY_D3THDT
$     dt      lcmdt
            99999
$  *DATABASE_GLSTAT
$     dt
          0.010
$  *DATABASE_MATSUM
$     dt
          0.010
$  *DATABASE_NODFOR
$     dt
          0.010
$  *DATABASE_NODAL_FORCE_GROUP
$     nsid      cid
Spot Weld Secures Two Plates

*CONSTRAINED_SPOTWELD

$ 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
$
$ *SET_NODE_LIST
$   sid
   1
*CONSTRANDED_SPOTWELD
Spot Weld Secures Two Plates

$ nid1  nid2  nid3  nid4  nid5  nid6  nid7  nid8
  231  232  233  234  235
$

$ Define Contacts

$ 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
$

$ 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.

$ 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 len1 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
  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, 70 nodes defined

... in total, 48 shells defined

$
*CONSTRAINED_SPOTWELD
Spot Weld Secures Two Plates

Results:

taurus g=d3plot
19
rx -80 state 28 view

phs3
seeforc
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 mm³ 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
$L
$LSTC Example
$L
$ Last Modified: September 5, 1997
$L
$ 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.
$L
$ Units: mm, s
$L
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$L
$$$$ Control Output
$L
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$L
*CONTROL_TERMINATION
$L  endtim  endcyc  dtmin  endneg  endmas
$L .200E-3
$L
*CONTROL_ENERGY
$L  hgen  rwen  slnten  rylen
$L  2  1  2
$L
*CONTROL_HOURGLASS
$L  ihq  qh
$L  4
$L
*CONTROL_TIMESTEP
$L  dtinit  scft  isdo  tslimt  dtms  lctm  erode  mslst
$L  0.50  0
$L
*DATABASE_BINARY_D3PLOT
$L  dt  lcdt
$L  0.0100E-3
$L
*DATABASE_BINARY_D3THDT
$L  dt  lcdt
$L  2.0000E-3
$L
*DATABASE_EXTENT_BINARY
$L  neigh  neips  maxint  strflg  sigflg  epsflg  rltflg  engflg
$L  cmpflg  ieverp  beamip
$L
*DATABASE_GLSTAT
$L  dt
$L  0.01e-04
$L
*DATABASE_NCFORC
$L  dt
$L  0.01e-04
$L
*DATABASE_NODOUT
Shell Rebounds from Plate Using Five Contact Types

$ 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

$ sfs  sfm  sst  mst  sfst  sfmt  fsf  vsf$

$ *SET_SEGMENT$
$ sid$
$ nl  n2  n3  n4$
101   103   104   102

$ *SET_SEGMENT$
$ sid$
$ nl  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

$ sfs  sfm  sst  mst  sfst  sfmt  fsf  vsf$

$ *SET_SEGMENT$
$ sid
*CONTACT
Shell Rebounds from Plate Using Five Contact Types

$$
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<tr>
<th></th>
<th>n1</th>
<th>n2</th>
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<td>13</td>
<td>14</td>
<td>19</td>
<td>18</td>
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$...

$$$$$$$$$$ Type 5, node to surface
 to make active, remove the $$ from the lines below

$$*CONTACT_NODES_TO_SURFACE
$$
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<th>vc</th>
<th>vdc</th>
<th>penchk</th>
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<th>sst</th>
<th>mst</th>
<th>sfst</th>
<th>sfmt</th>
<th>fsf</th>
<th>vsf</th>
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$$

$$*SET_NODE_LIST
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<th>nid6</th>
<th>nid7</th>
<th>nid8</th>
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<tbody>
<tr>
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<td>104</td>
<td>102</td>
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$$*SET_SEGMENT
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$$$$$$$$$$ Type 10, surface to surface
 to make active, remove the $$ from the lines below

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<td>14</td>
<td>19</td>
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</tbody>
</table>
Shell Rebounds from Plate Using Five Contact Types

$...

$ 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
$*$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
$*$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
*CONTACT

Shell Rebounds from Plate Using Five Contact Types

<p>| | | |</p>
<table>
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<tbody>
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<td>0.83333</td>
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</table>


t1 t2 t3 t4 nloc
2.0 2.0 2.0 2.0

$\text{$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$}$

$\text{$$$$  Define Nodes and Elements}$

$\text{$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$}$

$\text{$$$ Outer edge nodes of the Impacted Material are fixed in translation (tc = 7)}$

$\text{$$$}$

*NODE

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<tr>
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$\text{$$$$  SHELL ELEMENTS}$

$\text{$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$}$

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### Shell Rebounds from Plate Using Five Contact Types

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<td>103</td>
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$\*END$
*CONTACT
Shell Rebounds from Plate Using Five Contact Types

Results:

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

![Graph 1](image1.png)

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

![Graph 2](image2.png)
*CONTACT_ERODING_SURFACE_TO_SURFACE

Projectile Penetrates Plate

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 lcdn
  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 lcdn
  999999
$  
*DATABASE_GLSTAT
$  dt
  0.10
$  
*DATABASE_MATSUM
$  dt
  0.10
$  
```

70
*DATABASE_RCFORC
$ dt
  0.10
$
*DATABASE_SLEOUT
$ dt
  0.10
$

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$

*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.
$

*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

*

$ Define Parts and Materials
$

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$

*PART

$ pid      sid mid  eosid  hgid adpopt

Projectile
*CONTACT_ERODING_SURFACE_TO_SURFACE

Projectile Penetrates Plate

Plate

1 1 1

\$

\$

\\$\\$\\$\\$ Materials

\\$

\\$\\$ failure strain for erosion of the projectile and plate elements are

\\$\\$ set as:  \(fs = 0.8\)

\\$

*MAT_PLASTIC_KINEMATIC

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\\$... 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

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\$ Elements

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*ELEMENT_SOLID

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\$... 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
**CONTACT_ERODING_SURFACE_TO_SURFACE**

Projectile Penetrates Plate

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<th>7620</th>
<th>7628</th>
<th>7627</th>
<th>7659</th>
<th>7660</th>
<th>7668</th>
<th>7667</th>
</tr>
</thead>
</table>

$\text{*END}$
**CONTACT_ERODING_SURFACE_TO_SURFACE**

Projectile Penetrates Plate

**Results:**

- \texttt{taurus g=d3plot}
- \texttt{19}
- \texttt{rx -70 dist 27 view}

- State 8
- \texttt{m 1 center}
- \texttt{dam view}
LS-DYNA Manual Section:  *CONTACT NODES TO SURFACE

Additional Sections:

*CONSTRANGED 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.
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
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...>....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

*DATABASEExtent_BINARY
  neiph    neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
  cmpflg    ieverp    beamip

$
*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
$$$  Define Contacts - sliding interface definitions
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....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
$
*CONTACT_NODES_TO_SURFACE
Rigid Sphere Impacts a Plate at High Speed

$ sfs sfm sst mast 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 
$
$

$ lco/al 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 
$

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
**CONTACT_NODES_TO_SURFACE**

Rigid Sphere Impacts a Plate at High Speed

\[ \text{Boundary and Initial Conditions} \]

\[ \text{...>...1...>...2...>...3...>...4...>...5...>...6...>...7...>...8} \]

\[ \text{Fix all the edge nodes of the plate with SPC's.} \]

\[ \text{*BOUNDARY_SPC_NODE} \]

<table>
<thead>
<tr>
<th>nid</th>
<th>cid</th>
<th>dofx</th>
<th>dofy</th>
<th>dofz</th>
<th>dofrx</th>
<th>dofry</th>
<th>dofrz</th>
</tr>
</thead>
<tbody>
<tr>
<td>773</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>774</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

... in total, 236 SPC's defined.

\[ \text{Define Nodes and Elements} \]

\[ \text{...>...1...>...2...>...3...>...4...>...5...>...6...>...7...>...8} \]

\[ \text{*NODE} \]

<table>
<thead>
<tr>
<th>nid</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2.19971620E+01</td>
<td>-2.19971620E+01</td>
<td>-9.29716200E+00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>-2.41208560E+01</td>
<td>-4.26999400E+00</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

... in total, 4372 nodes defined.

\[ \text{Elements - Solids} \]

\[ \text{...>...1...>...2...>...3...>...4...>...5...>...6...>...7...>...8} \]

\[ \text{*ELEMENT_SOLID} \]

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
<th>n5</th>
<th>n6</th>
<th>n7</th>
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</tr>
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<tbody>
<tr>
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<td>1</td>
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<td>51</td>
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<td>2</td>
<td>47</td>
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<td>7</td>
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<tr>
<td>2</td>
<td>3</td>
<td>6</td>
<td>51</td>
<td>56</td>
<td>11</td>
<td>7</td>
<td>52</td>
<td>57</td>
<td>12</td>
</tr>
</tbody>
</table>

... in total, 384 solids defined.

\[ \text{Elements - Shells} \]

\[ \text{...>...1...>...2...>...3...>...4...>...5...>...6...>...7...>...8} \]

\[ \text{*ELEMENT_SHELL} \]

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>773</td>
<td>774</td>
<td>775</td>
<td>776</td>
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<tr>
<td>2</td>
<td>2</td>
<td>777</td>
<td>778</td>
<td>779</td>
<td>780</td>
</tr>
</tbody>
</table>

... in total, 900 shells defined.
*CONTACT_NODES_TO_SURFACE*

Rigid Sphere Impacts a Plate at High Speed

```
$ $$$ Define Tied Nodes with Failure Constraints $ $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8 $ 
$ $$$$ Tie all the adjacent corners of the shells together. Essentially, do $ $
$ $$$$ 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 
*END

*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`

---

Graphs showing force over time.
*CONTACT_NODES_TO_SURFACE*
Rigid Sphere Impacts a Plate at High Speed
**CONTACT_SINGLE_EDGE**  
Corrugated Sheet Contacts Edges

**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 monitor 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
```
*CONTACT_SINGLE_EDGE
Corrugated Sheet Contacts Edges

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85
```
*CONTACT_SINGLE_EDGE
Corrugated Sheet Contacts Edges

```
178  185  0  0
185  186  0  0
$
$
$$$  Force transducer defined to calculate contact forces on part 1.
$
*CONTACT_FORCE_TRANSUDER_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
  0.0  10.0  0.0  0.0  0.0  0.0
$

*SET_NODE_LIST
$  sid
  2
  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
$

$Define Parts and Materials$
$
*PART
$  pid  sid  mid  eosid  hgid  adpopt
plate-1  1  1  1
plate-2  2  1  1
```
*CONTACT_SINGLE_EDGE
Corrugated Sheet Contacts Edges

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 
$ tl  t2  t3  t4  nloc 
  2.00E-03 2.00E-03 2.00E-03 2.00E-03 
$ 
$ Define Nodes and Elements 
$ 
$ 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:

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

```
phs3
rcforc
resultant
```
**CONTACT_TIED_NODES_TO_SURFACE**
Discrete Nodes Tied to a Surface

**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 $40 \times 40 \times 1 \, \text{mm}^3$ 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.
*CONTACT_TIED_NODES_TO_SURFACE
Discrete Nodes Tied to a Surface

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
$  
$  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  
$  $$$$$$$  Control Ouput
$  
$  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  
$  *CONTROL_TERMINATION
$  endtim  endcyc  dtmin  endneg  endmas
  0.200E-03
$  
$  *CONTROL_HOURGLASS
$  ihq  qh
  4
$  
$  
$  *DATABASE_BINARY_D3PLOT
$  dt  lcdn
  0.010E-03
$  
$  *DATABASE_BINARY_D3THDT
$  dt  lcdn
  .0005E-03
$  
$  
$  *DATABASE_NODOUT
$  dt
  .0010E-03
$  
$  *DATABASE_HISTORY_NODE
$  id1  id2  id3  id4  id5  id6  id7  id8
  101  13  213
$  
$  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  
$  $$$$$$$  Define Contacts
$  
$  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  
$  $...>....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

90
Discrete Nodes Tied to a Surface

The nodes on the bottom of the box (part 2) are tied to the bottom plate (part 1).

*CONTACT_TIED_NODES_TO_SURFACE

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<th>sstyp</th>
<th>mstyp</th>
<th>sboxid</th>
<th>mboxid</th>
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*CONTACT_TIED_NODES_TO_SURFACE
Discrete Nodes Tied to a Surface

$*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
  ...
  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:

\begin{verbatim}
taurus g=d3plot
19
udg 1 time 1.6e-4 rx -70 view

phs3
nodout
grid z-disp
\end{verbatim}
*CONTACT_TIED_NODES_TO_SURFACE*
Discrete Nodes Tied to a Surface
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 $40 \times 40 \times 2$ 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.
*CONTACT_ENTITY
Rigid Sphere Impacts Plate

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  mslst
  $  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
Rigid Sphere Impacts Plate

$$$$$$ Contact Entity
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$\ldots\ldots1\ldots\ldots2\ldots\ldots3\ldots\ldots4\ldots\ldots5\ldots\ldots6\ldots\ldots7\ldots\ldots8$
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<th>styp</th>
<th>sf</th>
<th>df</th>
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</table>
$
|    bt   |    dt   |    so   |
|        |        |        |
|    xC   |    yC   |    zC   |    aX   |    aY   |    aZ   |
| 0.00   | 0.00   | 0.00   | 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
$
<table>
<thead>
<tr>
<th>sid</th>
<th>da1</th>
<th>da2</th>
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</tbody>
</table>
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$ Define Parts and Materials
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$\ldots\ldots1\ldots\ldots2\ldots\ldots3\ldots\ldots4\ldots\ldots5\ldots\ldots6\ldots\ldots7\ldots\ldots8$
$$$$ Part 1 shell: plate - elastic material
$$$$ Part 2 solid: sphere - rigid material ==> contact entity
$*

*PART
plate
$
<table>
<thead>
<tr>
<th>pid</th>
<th>sid</th>
<th>mid</th>
<th>eosid</th>
<th>hgid</th>
<th>adpopt</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
$
*PART
sphere
$
<table>
<thead>
<tr>
<th>pid</th>
<th>sid</th>
<th>mid</th>
<th>eosid</th>
<th>hgid</th>
<th>adpopt</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
</tbody>
</table>
Rigid Sphere Impacts Plate

$$\text{*** Contact Entity }$$

Mat\$  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
$
*SECTION\_SOLID
$ sid  elform
  2
$
$  Boundary and Initial Conditions
$
$  *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
$
$  *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

98
*CONTACT_ENTITY
Rigid Sphere Impacts Plate

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
$
edid 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

$
*CONTACT ENTITY
Rigid Sphere Impacts Plate

Results:

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

phs3
rbdout
oset -15 0 z-disp
**CONTROL_CONTACT**
Hemispherical Punch

**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.
*CONTROL_CONTACT
Hemispherical Punch

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

$$\text{Control Output}$$

*CONTROL_TERMINATION
$ endtim endcyc dtmin endneg endmas 6.0

$$\text{shell thickness is considered during contact: shlthk = 1}$$

*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

$$\text{membrane straining causes thickness change: istupd = 1}$$

*CONTROL_SHELL
$ wrpang itrist irnxx istupd theory bwc miter 1

*DATABASE_BINARY_D3PLOT
$ dt ldc 0.20

*DATABASE_EXTENT_BINARY
$ neigh neips maxint strflg sigflg epsflg rltflg engflg 1
$ cmpflg ieve rp beamip 1

*DATABASE_BINARY_D3THDT
$ dt ldc 12.00E+00

*DATABASE_GLSTAT
Hemispherical Punch

$ 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 $

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

$ 103
*CONTROL_CONTACT
Hemispherical Punch

$...

*PART

$ pid sid mid eosid hg id 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
  1.0 1.0 1.0 1.0 0.0
$

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

$$$$ Loading

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

$...

$$$$$$ 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
.
*CONTROL_CONTACT

Hemispherical Punch

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

*$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
Hemispherical Punch

*CONTROL_CONTACT

$ 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
Hemispherical Punch

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

$%
$$\text{SHELL ELEMENTS}$$
$
*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 $1000 \times 100 \times 10$ 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.
**CONTROL_DAMPING**

Cantilever Beam

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
$  for damping of 10
$  
$  for damping of 50
$  
$  Control Ouput
$  
$  Control TERMINATION
$  
$  CONTROL_CONTACT
$  
$  CONTROL_ENERGY
$  
$  CONTROL_HOURGLASS
$  

```plaintext
*KEYWORD
*TITLE
Cantilever Beam with Damping

$LSTC Example

Last Modified: September 11, 1997

Units: ton, mm, s, N, MPa, N-mm

Damping

for damping of 10

for damping of 50

Control Ouput

Control TERMINATION

CONTROL_CONTACT

CONTROL_ENERGY

CONTROL_HOURGLASS
```
*CONTROL_DAMPING
Cantilever Beam

4

$ *CONTROL_OUTPUT
$ npopt neecho nrefup iaccop opifs ipnint ikedit
  0 0 0 0 0 2 1000
$

$ *DATABASE_EXTENT_BINARY
$ neiph neips maxint strflg sigflg epsflg rltflg engflg
  1
$

$ *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
$
*CONTROL_DAMPING

Cantilever Beam

*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   ml   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).

<table>
<thead>
<tr>
<th>Node</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>0.000000E+00</td>
<td>1.000000E+02</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>1.000000E+02</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

... in total, 22 nodes defined.

<table>
<thead>
<tr>
<th>Node</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>9.000000E+02</td>
<td>1.000000E+02</td>
<td>0.000000E+00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>1.000000E+03</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>1.000000E+03</td>
<td>1.000000E+02</td>
<td>0.000000E+00</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Shell Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>17</td>
<td>19</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>19</td>
<td>21</td>
<td>22</td>
<td>20</td>
</tr>
</tbody>
</table>
Results:

```
taurus g=d3plot
rx -40 head Cantilever Beam (no damping)
time 0.2 u dg 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
*CONTROL_DAMPING
Cantilever Beam
**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.
*CONTROL_ENERGY
Bar Impact

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 Output
$$                       
$$                       
$$                       
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$                       
*CONTROL_TERMINATION
$ endtim  endcyc  dtmin  endneg  endmas
   82.10                   
$                       
*CONTROL_ENERGY
$ hgen  rwen  slnten  rylend
   2                       
$                       
*CONTROL_HOURGLASS
$ ihq  qh
   4                       
$                       
*CONTROL_OUTPUT
$ npopt  neecho  nrefup  iaccop  opifs  ipnint  ikedit
   0         0         0         0                   2      1000
$                       
$                       
*DATABASE_BINARY_D3PLOT
$ dt  lcdn
   5.0                     
$                       
*DATABASE_BINARY_D3THDT
$ dt  lcdn
   1.0                     
$                       
*DATABASE_GLSTAT
$ dt
   0.5                     
$                       
*DATABASE_NODOUT
$ dt/cycl  lcdn
   0.5                     
$                       
*DATABASE_HISTORY_NODE
$ id1  id2  id3  id4  id5  id6  id7  id8
   1333                     
$                       
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$                       
$$                       
$$$ 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
$$
<table>
<thead>
<tr>
<th>nsid</th>
<th>nsidex</th>
<th>boxid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
$$
vx vx vy vz vxe vye vze
0.0 0.0 -0.0227 0.0 0.0 0.0 0.0
$$
*DEFINE_BOX
$$
<table>
<thead>
<tr>
<th>boxid</th>
<th>xmm</th>
<th>xmx</th>
<th>ymn</th>
<th>ymx</th>
<th>zmn</th>
<th>zmx</th>
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<tbody>
<tr>
<td>2</td>
<td>-1.e6</td>
<td>1.e6</td>
<td>-1.e6</td>
<td>1.e6</td>
<td>0.50e-02</td>
<td>1.e6</td>
</tr>
</tbody>
</table>
$$
$$
*PART
$$
<table>
<thead>
<tr>
<th>pid</th>
<th>sid</th>
<th>mid</th>
<th>eosid</th>
<th>hgid</th>
<th>adpopt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
$$
*MAT_PLASTIC_KINEMATIC
$$
<table>
<thead>
<tr>
<th>mid</th>
<th>ro</th>
<th>e</th>
<th>pr</th>
<th>sigy</th>
<th>etan</th>
<th>beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.930</td>
<td>1.17</td>
<td>0.350</td>
<td>0.004</td>
<td>0.001</td>
<td>1.0</td>
</tr>
</tbody>
</table>
$$
src srp fs
0.0 0.0 0.0
$$
*SECTION_SOLID
$$
<table>
<thead>
<tr>
<th>sid</th>
<th>elform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
$$
$$
*NODE
$$
<table>
<thead>
<tr>
<th>node</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>5.330000E-02</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>1.067000E-01</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>
.$$ 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
$$
$$
$SSSSSS Solid Elements$
*CONTROL_ENERGY
Bar Impact

$ *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:

```plaintext
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
```

![Diagram of Bar Impact](image1)

![Diagram of Energy vs Time](image2)
*CONTROL_ENERGY
Bar Impact
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.
*CONTROL_SHELL
Hemispherical Load

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
$  
$  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
$\\text{\\texttt{\*CONTROL\_SHELL}}$

Hemispherical Load

$\\text{\\texttt{\\$\\$\\$ Loading}}$

$\\text{\\texttt{\\$\\$\\$ Load node 37, 38, 39 with 0.1667 lbs in both x and y direction.}}$

$\\text{\\texttt{*LOAD\_NODE\_POINT}}$

<table>
<thead>
<tr>
<th>nid</th>
<th>dof</th>
<th>lcid</th>
<th>sf</th>
<th>cid</th>
<th>m1</th>
<th>m2</th>
<th>m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>1</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>1</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>1</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>2</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>2</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>2</td>
<td>1</td>
<td>1.667E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\\text{\\texttt{\\$\\$\\$ Define Parts and Materials}}$

$\\text{\\texttt{\\$\\$\\$ Define Nodes and Elements}}$

Nodes 1, 2, 3 have fixed boundary conditions.

$\\text{\\texttt{*NODE}}$

<table>
<thead>
<tr>
<th>node</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>tc</th>
<th>rc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5.500000E-01</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>5.500000E-01</td>
<td>0.000000E+00</td>
<td>0.000000E+00</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>
**CONTROL_SHELL**

Hemispherical Load

... 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

$$\text{Shell Elements}$$

*ELEMENT_SHELL

... 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
```
*CONTROL_SHELL
Hemispherical Load
**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 \( \times \) 1.10 \( \times \) 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
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ *CONTROL_TERMINATION
$ endtim endcyc dtmin endneg endmas
 6.000E-02
$ *
*CONTROL_ENERGY
$ hgen rwen slnten rylene
 2 2
$
*CONTROL_HOURGLASS
$ ihq qh
 4
$
*CONTROL_SHELL
$ wrpang itrst irnxx istupd theory bwc miter
 -2 -1
$
*
*DATABASE_BINARY_D3PLOT
$ dt lcdt
 6.000E-04
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$ 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
**Twisted Cantilever Beam**

<table>
<thead>
<tr>
<th>abscissa</th>
<th>ordinate</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>1.000E+00</td>
<td>1.000E+00</td>
</tr>
</tbody>
</table>

```plaintext
*PART
  pid    sid    mid    eosid    hgid    adpopt
  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
  t1    t2    t3    t4    nloc
  4.000E-02  4.000E-02  4.000E-02  4.000E-02

*NODE
  node    x        y        z      tc     rc
  1  0.000000E+00  0.000000E+00  1.000000E+1  1      5
  2  1.950897E+00  0.000000E+00  9.807854E+0  0       0
  3  3.826834E+00  0.000000E+00  9.238795E+0  0       0
... in total, 61 nodes defined
  59  8.180990E+0  1.705178E+0  5.492155E+0  0       0
  60  7.794079E+0  3.370117E+0  5.281538E+0  0       0
  61  7.167934E+0  4.930554E+0  4.930554E+0  0       0

*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
```
**CONTROL_SHELL**
Twisted Cantilever Beam

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>1</td>
<td>59</td>
<td>10</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>47</td>
<td>1</td>
<td>60</td>
<td>15</td>
<td>20</td>
<td>61</td>
</tr>
<tr>
<td>48</td>
<td>1</td>
<td>61</td>
<td>20</td>
<td>25</td>
<td>45</td>
</tr>
</tbody>
</table>

$*END$
Results:

\texttt{taurus g=d3plot}

19

\texttt{ry 90 state 19 mono numc 15 contour 20}

\texttt{phs3 nodout black y-disp}
*CONTROL_SHELL
Twisted Cantilever Beam
**LS-DYNA Manual Section:**  *CONTROL_TIMESTEP

**Example:**  Billet Upset

**Filename:**  control_timestep.billet-forg.e

**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.
**Billet Upset**

List of LS-DYNA input deck:

*KEYWORD
*TITLE
BILLET UPSET
$
$
Last Modified: September 16, 1997
$
$
Units: lbf-s2/in, in, s, lbf, psi, lbf-in
$
$
*$CONTROL_TERMINATION
endtim endcyc dtmin endneg endmas
0.0015
$
*$CONTROL_TIMESTEP
dtinit scft isdo tslimt dtms lctm erode mslst
-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 lcdn
0.0001
$
*$DATABASE_EXTENT_BINARY
neiph neips maxint strflg sigflg epsflg rltflg engflg
cmpflg ieverp beamip
1
$
*$DATABASE_BINARY_D3THDT
dt lcdn
999999
$
*$DATABASE_GLSTAT
dt
0.00001
$
*$DATABASE_MATSUM
dt
0.00001
$
*$DATABASE_RBDOUT
dt
0.00001
$
*$DATABASE_RCFORC
*CONTROL_TIMESTEP

Billet Upset

$\begin{align*}
\text{dt} & = 0.00001 \\
\end{align*}$

Loading - PRESCRIBED_MOTION_RIGID

$\begin{align*}
\text{*BOUNDARY_PRESCRIBED_MOTION_RIGID} \\
\text{mid} & \quad \text{dof} \quad \text{vad} \quad \text{lcid} \quad \text{sf} \quad \text{vid} \\
2 & \quad 3 \quad 0 \quad 1 \quad 1.000E+00 \\
\end{align*}$

*DEFINE_CURVE

$\begin{align*}
\text{lcid} & \quad \text{sidr} \quad \text{scla} \quad \text{sclo} \quad \text{offa} \quad \text{offo} \\
1 & \quad \text{abscissa} \quad \text{ordinate} \\
0.000E+00 & \quad 0.000E+00 \\
5.000E-05 & \quad -4.931E+00 \\
1.000E-04 & \quad -1.960E+01 \\
1.500E-04 & \quad -4.365E+01 \\
2.000E-04 & \quad -7.649E+01 \\
2.500E-04 & \quad -1.173E+02 \\
3.000E-04 & \quad -1.651E+02 \\
3.500E-04 & \quad -2.187E+02 \\
4.000E-04 & \quad -2.767E+02 \\
4.500E-04 & \quad -3.378E+02 \\
5.000E-04 & \quad -4.005E+02 \\
5.500E-04 & \quad -4.632E+02 \\
6.000E-04 & \quad -5.243E+02 \\
6.500E-04 & \quad -5.823E+02 \\
7.000E-04 & \quad -6.359E+02 \\
7.500E-04 & \quad -6.837E+02 \\
8.000E-04 & \quad -7.245E+02 \\
8.500E-04 & \quad -7.573E+02 \\
9.000E-04 & \quad -7.814E+02 \\
9.500E-04 & \quad -7.961E+02 \\
1.000E-03 & \quad -8.010E+02 \\
1.050E-03 & \quad -7.961E+02 \\
1.100E-03 & \quad -7.814E+02 \\
1.150E-03 & \quad -7.573E+02 \\
1.200E-03 & \quad -7.245E+02 \\
1.250E-03 & \quad -6.837E+02 \\
1.300E-03 & \quad -6.359E+02 \\
1.350E-03 & \quad -5.823E+02 \\
1.400E-03 & \quad -5.243E+02 \\
1.450E-03 & \quad -4.632E+02 \\
1.500E-03 & \quad -4.005E+02 \\
1.550E-03 & \quad -3.378E+02 \\
1.600E-03 & \quad -2.767E+02 \\
1.650E-03 & \quad -2.187E+02 \\
1.700E-03 & \quad -1.651E+02 \\
1.750E-03 & \quad -1.173E+02 \\
1.800E-03 & \quad -7.649E+01 \\
1.850E-03 & \quad -4.365E+01 \\
1.900E-03 & \quad -1.960E+01 \\
1.950E-03 & \quad -4.931E+00 \\
2.000E-03 & \quad 0.000E+00 \\
2.200E-03 & \quad 0.000E+00 \\
\end{align*}$
*CONTROL_TIMESTEP
Billet Upset

$$
\text{Define Contacts}
$$

$$
\text{CONTACT_NODES_TO_SURFACE}
$$

$$
\text{Define Parts and Materials}
$$

$$
\text{PART}
$$

$$
\text{materials}
$$

$$
\text{sections}
$$
*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

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

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

*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 rcfour ascii output file.

**Results:**

During the drawing operation, the mesh is refined considerably.
Deep Drawing with Adaptivity

List of LS-DYNA input deck:

*KEYWORD
*TITLE
deep drawing - blankholder contact damping, mesh refinement

$ 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 Output

*CONTROL_TERMINATION
endtim endcyc dtmin endneg endmas
700.0

*CONTROL_CONTACT
slsfac rwpnal islchk shlthk penopt thkchg orien
0.01 0.2 1
usrstr usrfrc nsbcs interm xpene sshthk ecdt tiedprj

*CONTROL_ENERGY
hgen rwen slnten rylen
2 2 2

*CONTROL_OUTPUT
npopt neecho nrefup iaccop opifs ipnint ikedit
1 3

*CONTROL_SHELL
wbpang itrist irnxx istupd theory bwc miter
20.0 1 0 1

*CONTROL_TIMESTEP
dtinit scft isdo tslimit dtms lctm erode mslst
0.0 0.0 0.0 -0.25 0 0

$
*DATABASE_BINARY_D3PLOT
$       dt       lcdn
     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      scln      sclp      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      scln      sclp      offa      offo
     1
$           abscissa            ordinate
Deep Drawing with Adaptivity

$ 0.000E+00  0.000E+00
 1.000E+00  2.912E-03
 2.000E+00  5.540E-03
 3.000E+00  7.625E-03
 4.000E+00  8.963E-03
 5.000E+00  9.425E-03
 6.000E+00  8.963E-03
 7.000E+00  7.625E-03
 8.000E+00  5.540E-03
 9.000E+00  2.912E-03
1.000E+00  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
$    2 2 2 -1.0

$  *DEFINE_CURVE
$    2 8.000E-05 8.000E-05

$  Define Parts and Materials

$  *PART
$    1 1 2 0 0 0 0 0
$    2 1 2 0 0 0 0 0
$    3 1 1 0 0 0 0 0
$    4 1 2 0 0 0 0 0

$  *MAT_PLASTIC_KINEMATIC
$    1 2.700E+00 0.690E+00 3.000E-01 8.180E-04 0.010E+00 1.000E+00 0.000E+00

$  *MAT_RIGID
$    0.000E+00 0.000E+00
Deep Drawing with Adaptivity

\[
\begin{array}{cccccccc}
2 & 8.450E-00 & 0.690E+00 & 3.000E-01 & 0.000E+00 & 0.000E+00 & 0.000E+00 & 0.000E+00 \\
\end{array}
\]

\[
\begin{array}{cccccccc}
\$ & \text{cmo} & \text{con1} & \text{con2} \\
0.000E+00 & 0.000E+00 \\
\$ & \text{lco/1} & \text{a2} & \text{a3} & \text{v1} & \text{v2} & \text{v3} \\
\$
\end{array}
\]

\[
\begin{array}{cccccccc}
\$ & \text{SECTION_SHELL} \\
\$ & \text{sid} & \text{elform} & \text{shrf} & \text{nip} & \text{propt} & \text{qr/irid} & \text{icomp} \\
1 & 2 & 1. & 5. & 0. & 0. & 0 \\
\$ & \text{t1} & \text{t2} & \text{t3} & \text{t4} & \text{nloc} \\
.100 & .100 & .100 & .100 & .100 \\
\$
\end{array}
\]

Define Contacts - sliding interface definitions

\[
\begin{array}{cccccccc}
\$ & \text{CONTACT_ONE_WAY_SURFACE_TO_SURFACE} \\
\$ & \text{ssid} & \text{msid} & \text{sstyp} & \text{mstyp} & \text{sboxid} & \text{mboxid} & \text{spr} & \text{mpr} \\
3 & 1 & 2 & 2 & 0 & 0 & 0 & 0 \\
\$ & \text{fs} & \text{fd} & \text{dc} & \text{vc} & \text{vdc} & \text{penchk} & \text{bt} & \text{dt} \\
.2 & .2 & 0 & 0 & 20. & 0 & 0 & 0 \\
\$ & \text{sfs} & \text{sfm} & \text{sst} & \text{mst} & \text{sfst} & \text{sfmt} & \text{fsf} & \text{vsf} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\$
\end{array}
\]

Contact between blank (slaves) and punch (master)

\[
\begin{array}{cccccccc}
\$ & \text{CONTACT_ONE_WAY_SURFACE_TO_SURFACE} \\
3 & 2 & 2 & 2 & 0 & 0 & 0 & 0 \\
.2 & .2 & 0 & 0 & 20. & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\$
\end{array}
\]

Contact between blank (slaves) and binder (master)

\[
\begin{array}{cccccccc}
\$ & \text{CONTACT_ONE_WAY_SURFACE_TO_SURFACE} \\
3 & 4 & 2 & 2 & 0 & 0 & 0 & 0 \\
.2 & .2 & 0 & 0 & 20. & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\$
\end{array}
\]

Contact between blank (slaves) and die (master)

\[
\begin{array}{cccccccc}
\$ & \text{CONTACT_ONE_WAY_SURFACE_TO_SURFACE} \\
3 & 2 & 2 & 2 & 0 & 0 & 0 & 0 \\
.2 & .2 & 0 & 0 & 20. & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\$
\end{array}
\]

SET_PART

\[
\begin{array}{cccccccc}
\$ & \text{sid} \\
3 \\
\$
\end{array}
\]

\[
\begin{array}{cccccccc}
\$ & \text{pid} \\
3 \\
\$
\end{array}
\]

SET_PART

\[
\begin{array}{cccccccc}
\$ & \text{SET_PART} \\
1 \\
\$
\end{array}
\]

\[
\begin{array}{cccccccc}
\$ & \text{SET_PART} \\
2 \\
\$
\end{array}
\]

145
CONTROL_ADAPTIVE
Deep Drawing with Adaptivity

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-06-0.100000000E+00-0.800000000E+01       7       7

$.

$define 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:

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

state 15
view
```
*CONTROL_ADOPTIVE
Deep Drawing with Adaptivity
**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.
*CONTROL_ADAPTIVE
Square Crush Tube with Adaptivity

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
$
$XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
$
$%%%%
$XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
$
$...>....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
$
$XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
$
$%%%%
$XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
$
$...>....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
$
$XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
$
$\textbf{Initial Conditions}$

$\textbf{Constraints}$

$\textbf{Define Contacts - sliding interface definitions}$

$\textbf{Set Part}$
*CONTROL_ADAPTIVE
Square Crush Tube with Adaptivity

$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $  
$ $ $$$  Define Parts and Materials $ $ 
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $  
$ ..>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8 $  
$ *PART $ pid sid mid eosid hgid grav adpopt square-tube 1 1 1 0 0 0 0 1 $ 
$ $ 
$ *MAT_PLASTIC_KINEMATIC $ mid ro e pr sigy etan beta 1 7.850E-09 1.994E+05 3.000E-01 3.366E+02 1.000E+00 1.000E+00 0.000E+00 $ src srp fs $ $ 
$ $ 
$ *SECTION_SHELL $ sid elform shrf nip propt qr/irid icomp 1 2 1 3 0 0 0 $ t1 t2 t3 t4 nloc 1.2 1.2 1.2 1.2 $ 
$ $ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $  
$ $ $$$  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 $ $
Square Crush Tube with Adaptivity

```
$ *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
```
*CONTROL_ADAPTIVE
Square Crush Tube with Adaptivity

Results:

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

![Graph 1](image1.png)

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

![Graph 2](image2.png)
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_COORDINATEVECTOR.

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-s^2/in, in, s, lbf, psi, lbf-in

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$    $$$  Control Output
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$.....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ $$
*CONTROL_TERMINATION
$    endtim    endcyc     dtmin    endeng    endmas
$  0.0004
$ $  
*CONTROL_ENERGY
$    hgen      rwen    slnten     rylen
$    2         2
$ $  
*CONTROL_OUTPUT
$    npopt    neecho    nrefup    iaccop    opifs    ipnint    ikedit
$    1         3
$ $  
*CONTROL_SHELL
$    wrpang    itrst     irnxx     istupd    theory    bwc    miter
$    1         2         1
$ $  
*DATABASE_BINARY_D3PLOT
$    dt      lcdt
$  0.00002
$ $  
*DATABASE_GLSTAT
$    dt
$  0.00002
$ $  
*DATABASE_MATSUM
$    dt
$  0.00002
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $    $$$  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
$ $  
```

---

156
**CONTROL_ADAPTIVE**

Cylinder Undergoing Deformation with Adaptivity

```plaintext
# Define Parts and Materials

*PART
  pid sid mid eosid hgid grav adpopt
  a16061-t6

*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

*SECTION_SHELL
  sid elform shrf nip propt qr/irid icomp
  1 2 1. 5. 0. 0. 0.

*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.

*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
```
\*CONTROL_ADAPTIVE

Cylinder Undergoing Deformation with Adaptivity

\$
\$
\$
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\$

\*INITIAL_VELOCITY_NODE
\$

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158
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
```
*CONTROL_ADAPTIVE*
Cylinder Undergoing Deformation with Adaptivity
DAMPING_GLOBAL

Tire Bounces on the Ground and Damps Out

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.
*DAMPING_GLOBAL
Tire Bounces on the Ground and Damps Out

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
Tire Bounces on the Ground and Damps Out

* DAMPING_GLOBAL

0.1

$...

$...

* CONTROL_DYNAMIC_RELAXATION

$ nrcyck drtol drfctr drterm tssfdr irelal edttl idrflg
  100 1.0e-3  0.995  0.9

$...

* LOAD_BODY_Z

$ lcid df lciddr xc yc zc
  1 9.810E-03

$...

* DEFINE_CURVE

$ lcid sidr scla sclo offa offo
  1

$...

* 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

```
*PART
$     pid sid mid eosid hgid grav adpopt
wheel
  35   1   1
tire
  36   1   1
ground
  76   76   2
$

*PART
$     pid sid mid eosid hgid grav adpopt
wheel
  35   1   1
tire
  36   1   1
ground
  76   76   2
$

*MAT_PIECEWISE_LINEAR_PLASTICITY
$     mid e 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 e ro e pr n couple m alias
  2 0.783E-05  200.0    0.3
$

*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

```
*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+1
```
Tire Bounces on the Ground and Damps Out

... 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
*DAMPINGLOBAL*
Tire Bounces on the Ground and Damps Out

Results:

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

![Diagram of tire bouncing on the ground with damping](image1)

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

![Graph showing total and damping energy over time](image2)
**DEFORMABLE_TO_RIGID**

Interaction of Pendulums

**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.
**DEFORMABLE_TO_RIGID**

Interaction of Pendulums

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 Output

$ 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  nabcis  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       lcdn
1.00

$ DATABASE_EXTENT_BINARY
$ neigh  neips  maxint  strflg  sigflg  epsflg  rltflg  engflg
$ cmpflg  ieverp  beamip
1
$ DATABASE_BINARY_D3THDT
$ dt       lcdn
999999
*DEFORMABLE_TO_RIGID
Interaction of Pendulums

$ *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
  $
  $
*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

  $
  $
*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
  $
  $
  $
**DEFORMABLE_TO_RIGID**

Interaction of Pendulums

```plaintext
$ $$$ Boundary and Initial Conditions $
$ 

$\cdots \cdots 1 \cdots \cdots 2 \cdots \cdots 3 \cdots \cdots 4 \cdots \cdots 5 \cdots \cdots 6 \cdots \cdots 7 \cdots \cdots 8$
$ $$$ Constrain translation of end points of beams $
$ *BOUNDARY_SPC_NODE
$ 

<table>
<thead>
<tr>
<th>nid</th>
<th>cid</th>
<th>dofx</th>
<th>dofy</th>
<th>dofz</th>
<th>dofrx</th>
<th>dofry</th>
<th>dofrz</th>
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<tr>
<td>45004</td>
<td>0</td>
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</tbody>
</table>

$ $$$ The nodes within box 5 are given an initial velocity. $
$ *INITIAL_VELOCITY
$ 

<table>
<thead>
<tr>
<th>nsid</th>
<th>nsidx</th>
<th>boxid</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
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</table>

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<tr>
<th>vx</th>
<th>vy</th>
<th>vz</th>
<th>wx</th>
<th>wy</th>
<th>wz</th>
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<tbody>
<tr>
<td>0.0</td>
<td>-12.0</td>
<td>0.0</td>
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</table>

$ $$$ Define Parts and Materials $
$ 

$\cdots \cdots 1 \cdots \cdots 2 \cdots \cdots 3 \cdots \cdots 4 \cdots \cdots 5 \cdots \cdots 6 \cdots \cdots 7 \cdots \cdots 8$
$ $$$ SPHERES $
$ *PART
$ 

<table>
<thead>
<tr>
<th>pid</th>
<th>sid</th>
<th>mid</th>
<th>eosid</th>
<th>hgid</th>
<th>adpopt</th>
</tr>
</thead>
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<td>1</td>
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<td>1</td>
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<td></td>
<td></td>
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<tr>
<td>2</td>
<td>2</td>
<td>1</td>
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</table>

$ $$$ Materials $
$ $ Aluminum $ 

$ *MAT_PLASTIC_KINEMATIC $ 

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<tr>
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<th>e</th>
<th>pr</th>
<th>sigy</th>
<th>etan</th>
<th>beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.70e-6</td>
<td>68.9</td>
<td>0.330</td>
<td>0.286</td>
<td>0.00689</td>
<td></td>
</tr>
</tbody>
</table>

$ $$$ Sections $ 
$ $ 

*SECTION_SHELL
```
Interaction of Pendulums

*DEFORMABLE_TO_RIGID

sid  elform  shrf  nip  propt  qr/irid  icomp
1    2       1.0  1.0  1.0

*SECTION_SHELL

sid  elform  shrf  nip  propt  qr/irid  icomp
2    2       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

Define Nodes

node  x    y    z  tc  rc
1   -1.08660250E+02  9.133975000E+01 -3.66025000E+00
### Interaction of Pendulums

```
2  -1.0946480E+02  9.33191400E+01  -4.49648000E+00
3  -1.10108300E+02  9.54564100E+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

45000  5.000000000E+00  1.000000000E+02  -5.00000000E+01
45001  5.000000000E+00  1.000000000E+02  6.000000000E+01
45002  1.500000000E+01  1.000000000E+02  -5.00000000E+01
45003  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  1.816697500E+01  8.920056610E+00  1.067986974E+01

Define Elements

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

766  2  770  643  651  771
767  2  771  651  659  772
768  2  772  659  667  723

*END
```
**DEFORMABLE_TO_RIGID**

Interaction of Pendulums

*KEYWORD

*TITLE

Pendulum with 2 spheres colliding

$$$

$ Last Modified: September 16, 1997

$ Units: mm, kg, ms, kN, GPa, kN-mm

$ $$$$ Switch spheres to deformables

$ $$$$ Increase d3plot output frequency to capture deformation of impact better.

$ *DATABASE_BINARY_D3PLOT

$ *END
Results:

```plaintext
taurus g=d3plot
19
state 1 angle 1 vect v
```

```
phs3
nodout
x-vel 374 713
```
*INTEGRATION_SHELL
Cantilever Beam with Lobotto Integration

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 in³ 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 Lobatto Integration

List of LS-DYNA input deck:

*KEYWORD
*TITLE
Lobatto 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 lcdn
$ 0.0003
$ *
$ DATABASE_BINARY_D3THDT
$ dt lcdn
$ 10.
$ *
$ DATABASE_EXTENT_BINARY
$ neiph neips maxint strflg sigflg epsflg rltflg engflg
$ 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
$

$*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      0
  0.000E+00      0.000E+00
  8.000E-03      1.667E-03
  1.534E-02      1.667E-03
$

$*DAMPING_GLOBAL
$   lcid    valdmp
  2      0.0
$

$*DEFINE_CURVE
$   lcid    sidr    scla    sclo    offa    offo
  2
  a      0
  0.000E+00      0.000E+00
  8.000E-03      0.000E+00
  1.000E-02      2.353E+03
  1.534E-02      2.353E+03
$

$ PART
$   pid    sid    mid    eosid    hgid    adpopt
Cantilever Beam - Aluminum
  1      1      1
*INTEGRATION_SHELL
Cantilever Beam with Lobatto 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  sxp  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 9.666667E-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
### Cantilever Beam with Lobotto Integration

<table>
<thead>
<tr>
<th></th>
<th>59</th>
<th>1</th>
<th>60</th>
<th>91</th>
<th>92</th>
<th>61</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1</td>
<td>61</td>
<td>92</td>
<td>93</td>
<td>62</td>
<td></td>
</tr>
</tbody>
</table>

\$\ *

\*END
*INTEGRATION_SHELL
Cantilever Beam with Lobotto Integration

Results:

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

![Diagram of Lobotto Integration](image1)

```
phs3
nodout
z-disp
```

![Diagram of Modal Point Z-Displacement](image2)
**INTERFACE_COMPONENT**
An Interface File Controls the Response of a Cube

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 $40 \times 40 \times 2$ 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.
**INTERFACE_COMPONENT**
An Interface File Controls the Response of a Cube

List of LS-DYNA Input Deck:

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

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An Interface File Controls the Response of a Cube

$          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
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
$ $ *INITIAL VELOCITY
$      nsid    nsidex    boxid
  1
$      vx    vy    vz
  0.0    0.0  -100000.0$
$
$ *DEFINE_BOX
$      boxid    xmm    xmx    ymn    ymx    zmn    zmx
  1    15.0    25.0    15.0    25.0    10.0    20.0$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$  Contact - Sliding Interfaces
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
$ $$$$$$$  Contact between the bottom of the cube (segment set 1) and the plate.
*INTERFACE_COMPONENT
An Interface File Controls the Response of a Cube

$ *CONTACT_SURFACE_TO_SURFACE
$  ssid  msid  sstyp  mstyp  sboxid  mboxid  spr  mpr
$   1     2     1      2       1       2       1     2
$  fs    fd    dc    vc    vdc    penchk    bt    dt
$  sfs   sfm   sst   mst   sfst   sfm   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
   9    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

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An Interface File Controls the Response of a Cube

$ *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

$ *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
$ $ $$$ Control Ouput
$ $ $$$ Control Ouput
$ $ ...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ $ *CONTROL_TERMINATION
$  endtim  endcyc  dtmin  endneg  endmas
$  0.0003
$ *CONTROL_ENERGY

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*INTERFACE_COMPONENT
An Interface File Controls the Response of a Cube

$     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    mslst
        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
$

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

$...>....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
## INTERFACE_COMPONENT

An Interface File Controls the Response of a Cube

### Define Parts and Materials

```plaintext
*PART
pid sid mid eosid hgid adpopt
1 1 1
```

### Define Nodes and Elements

```plaintext
*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
```

```plaintext
*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
*INTERFACE_COMPONENT
An Interface File Controls the Response of a Cube

Results:

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

```
phs3
nodout
oset -1.5e5 1.0e5 z-vel 101
```
*INTERFACE_COMPONENT
An Interface File Controls the Response of a Cube

Results:

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

```
phs3
nodout
oset -1.5e5 1.0e5 z-vel 201
```
*INTERFACE_COMPONENT
An Interface File Controls the Response of a Cube
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 mm³. 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_SECFCORC).

Reference:

Schweizerhof, K. and Weimer, K.
*LOAD_BODY_GENERALIZED
Rotating Elements

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
*LOAD_BODY_GENERALIZED
Rotating Elements

$ 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
*LOAD_BODY_GENERALIZED

Rotating Elements

$ 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

  abcissa 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
  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   0.00000E+00   0.00000E+00   0.00000E+00    7    0
  2   0.00000E+00  1.00000E+02   0.00000E+00    6    0
  3  1.00000E+02  0.00000E+00  0.00000E+00    0    0
  4  1.00000E+02  1.00000E+02  0.00000E+00    0    0
  5  2.00000E+02  0.00000E+00  0.00000E+00    0    0
  6  2.00000E+02  1.00000E+02  0.00000E+00    0    0

$

*ELEMENT_SHELL

$ eid pid n1 n2 n3 n4
  1    1    1    3    4    2
  2    1    3    5    6    4

$ *END

194
Results:

```plaintext
taurus g=d3plot
19
ytran -80 rx 40 ndpt s 3 over vec velo
```

![Diagram](image1)

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

![Diagram](image2)
*LOAD_BODY_GENERALIZED
Rotating Elements
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/ms² 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.
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  rlyen
     2     2
$
$*DATABASE_BINARY_D3PLOT
$  dt  lcdn
     10.0
$*DATABASE_BINARY_D3THDT
$  dt  lcdn
     999999
$*DATABASE_GLSTAT
$  dt
     0.2
$*DATABASE_MATSUM
Tire Under Gravity Loading Bounces on a Rigid Wall

$ 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$

$*$ Rigid Wall - The Ground$

$*$LOAD_BODY_Z$

 lcid df lciddr xc yc zc
1 9.810E-03$

$*DEFINE_CURVE$

 lcid sidr scla sclo offa offo
1 0.00 1.000
1000.00 1.000$

$*$ Rigid Wall - The Ground$

$*$SET_NODE_COLUMN$

 sid nid
1 8901 8904 8911 8912
*LOAD_BODY_Z
Tire Under Gravity Loading Bounces on a Rigid Wall

8913
8914
8919
8920
8921
8922

Define Parts and Materials

$ *PART
$ pid sid mid eosid hgid grav adpopt
wheel
  35  1  1
tire
  36  1  1

Materials

*MAT_PIECEWISE_LINEAR_PLASTICITY

$ 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

$ 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

Define Nodes and Elements

$ *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
Tire Under Gravity Loading Bounces on a Rigid Wall

*LOAD_BODY_Z

8931  2.7900000000E+02  -7.5400000000E+02  0.0000000000E+00  0  0
8932  2.5776200000E+02  -7.5400000000E+02  1.0676900000E+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
*LOAD_BODY_Z*
Tire Under Gravity Loading Bounces on a Rigid Wall

Results:

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

![Diagram 1](image1)

```
phs3
rwforc
normal
```

![Diagram 2](image2)
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 $7.5 \times 7.5 \times 100$. 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 specimen 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.
*MAT_FRAZER_NASH_RUBBER_MODEL
Frazer-Nash Single Element

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  rylene
  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
**MAT_FRAZER_NASH_RUBBER_MODEL**
Frazer-Nash Single Element

\[
\begin{align*}
\$ & \quad \text{dt} \\
& \quad 0.1 \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{DATABASE\_HISTORY\_NODE} & \\
\$ & \quad \text{id1} \quad \text{id2} \quad \text{id3} \quad \text{id4} \quad \text{id5} \quad \text{id6} \quad \text{id7} \quad \text{id8} \\
1 & \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{BOUNDARY\_PRESCRIBED\_MOTION\_NODES} & \\
\$ & \quad \text{nid} \quad \text{dof} \quad \text{vad} \quad \text{lcid} \quad \text{sf} \quad \text{vid} \\
1 & \quad 4 \quad 2 \quad 1 \quad 4.000\times10^{-2} \quad 1 \\
2 & \quad 4 \quad 2 \quad 1 \quad 4.000\times10^{-2} \quad 1 \\
3 & \quad 4 \quad 2 \quad 1 \quad 4.000\times10^{-2} \quad 1 \\
4 & \quad 4 \quad 2 \quad 1 \quad 4.000\times10^{-2} \quad 1 \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{DEFINE\_VECTOR} & \\
\$ & \quad \text{vid} \quad \text{xt} \quad \text{yt} \quad \text{zt} \quad \text{xh} \quad \text{yh} \quad \text{zh} \\
1 & \quad 0.000E+00 \quad 0.000E+00 \quad 0.000E+00 \quad 0.000E+00 \quad 0.000E+00 \quad 0.000E+00 \quad 1.000E+00 \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{DEFINE\_CURVE} & \\
\$ & \quad \text{lcid} \quad \text{sidr} \quad \text{scla} \quad \text{sclo} \quad \text{offa} \quad \text{offo} \\
1 & \quad \text{abscissa} \quad \text{ordinate} \\
& \quad 0.00000000E+00 \quad 0.00000000E+00 \\
& \quad 2.00000000E+00 \quad 7.13000011E+00 \\
& \quad 4.00000000E+00 \quad 1.35200005E+01 \\
& \quad 6.00000000E+00 \quad 1.86100005E+01 \\
& \quad 8.00000000E+00 \quad 2.18700008E+01 \\
& \quad 1.00000000E+01 \quad 2.30000000E+01 \\
& \quad 1.20000000E+01 \quad 2.18700008E+01 \\
& \quad 1.40000000E+01 \quad 1.86100005E+01 \\
& \quad 1.60000000E+01 \quad 1.35200005E+01 \\
& \quad 1.80000000E+01 \quad 7.13000011E+00 \\
& \quad 2.00000000E+01 \quad 0.00000000E+00 \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{PART} & \\
\$ & \quad \text{pid} \quad \text{sid} \quad \text{mid} \quad \text{eosid} \quad \text{hgid} \quad \text{adpopt} \\
\text{Rubber} & \quad 1 \quad 1 \quad 1 \\
\$
\end{align*}
\]

\[
\begin{align*}
*\text{MAT\_FRAZER\_NASH\_RUBBER\_MODEL} & \\
\$ & \quad \text{mid} \quad \text{ro} \quad \text{pr} \quad \text{c100} \quad \text{c200} \quad \text{c300} \quad \text{c400} \\
1 & \quad 1.254\times10^{-6} \quad 0.495 \quad 1.000E+00 \quad 0.000E+00 \\
\$
\end{align*}
\]

\[
\begin{align*}
\$ & \quad \text{c110} \quad \text{c210} \quad \text{c010} \quad \text{c020} \quad \text{exit} \quad \text{emax} \quad \text{emin} \\
& \quad 1.000E+00 \quad 0.000E+00 \quad 1.000E+00 \quad 1.000E+00 \quad 1.000E+00 \quad 9.000E-01-9.000E-01 \\
\$
\end{align*}
\]
*[MAT_FRAZER_NASH_RUBBER_MODEL]

Frazer-Nash Single Element

$ sg1 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
0.000000000E+00 0.000000000E+00
6.07299991E-03 3.59800004E-04
1.24500003E-02 6.25399989E-03
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
6.94399988E-02 1.14000001E-02
7.2779982E-02 1.26200002E-02
7.60900006E-02 1.41899996E-02
7.94499964E-02 1.59000009E-02
8.28600004E-02 1.77500006E-02
8.4049997E-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 7.5000000000E+00 0.0000000000E+00 1.0000000000E+01 0 0
2 7.5000000000E+00 7.5000000000E+00 1.0000000000E+01 0 0
3 0.0000000000E+00 7.5000000000E+00 1.0000000000E+01 0 0
4 0.0000000000E+00 0.0000000000E+00 1.0000000000E+01 0 0
5 7.5000000000E+00 0.0000000000E+00 0.0000000000E+00 3 0
6 7.5000000000E+00 7.5000000000E+00 0.0000000000E+00 3 0
7 0.0000000000E+00 7.5000000000E+00 0.0000000000E+00 3 0
8 0.0000000000E+00 0.0000000000E+00 0.0000000000E+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

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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
*MAT_FRAZER_NASH_RUBBER_MODEL*
Frazer-Nash Single Element
**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
$  Control TERMINATION
$  Control_CONTACT
$  Control_HOURGLASS
$  DATABASE_BINARY_D3PLOT
$  INITIAL_VELOCITY
$  SET_NODE_LIST

All nodes except nodes in node set 1 are given an initial velocity.
Node set 1 contains the nodes of the wall.
$ MAT_PIECEWISE_LINEAR_PLASTICITY 
Piecewise Linear Plasticity Fragmenting Plate 
$

<table>
<thead>
<tr>
<th>ssid</th>
<th>msid</th>
<th>sstyp</th>
<th>mstyp</th>
<th>sboxid</th>
<th>mboxid</th>
<th>spr</th>
<th>mpr</th>
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<td>2</td>
<td>3</td>
<td></td>
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</tbody>
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<th>fd</th>
<th>dc</th>
<th>vc</th>
<th>vdc</th>
<th>penchk</th>
<th>bt</th>
<th>dt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

| sfs  | sfm  | sst   | mst   | sfst   | sfmt   | fsf  | vsf |

$ SET_PART_LIST 

<table>
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$ MAT_PIECEWISE_LINEAR_PLASTICITY 

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$ SECTION_SHELL 

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<th>shrf</th>
<th>nip</th>
<th>propt</th>
<th>qr/irid</th>
<th>icomp</th>
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$ Define Parts and Materials 

$ Define Nodes and Elements 

Nodes 1282, 1283, 1284, 1285 are fixed - nodes of the wall.
MAT_PIECEWISE_LINEAR_PLASTICITY
Piecewise Linear Plasticity Fragmenting Plate

*NODE
$ node    x    y    z    tc    rc
  1  0.000000E+00  0.000000E+00  0.000000E+00   0   0
...
  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
...
  1201    3    1282    1283    1284    1285
$

*END
Results:

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

![Diagram](attachment:diagram.png)

state 21
view

![Diagram](attachment:diagram2.png)
*MAT_PIECEWISE_LINEAR_PLASTICITY*

Piecewise Linear Plasticity Fragmenting Plate
**MAT_RIGID**

Rigid Sliding Block in Local Coordinate System

**LS-DYNA Manual Section:** *MAT_RIGID*

**Additional 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.
**MAT_RIGID**

Rigid Sliding Block in Local Coordinate System

List of LS-DYNA input deck:

*KEYWORD
*TITLE
Sliding Block
$  
$  LSTC Example
$  
$  Last Modified: September 18, 1997
$  
$  Units: lbf-s/2/in, in, s, lbf, psi, lbf-in
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$$$$  Control Ouput  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8  
$  
*CONTROL_TERMINATION  
$  endtim endcyc dtmin endneg endmas
1.000E-02
$  
*DATABASE_BINARY_D3PLOT
$  dt lcdt
5.000E-04
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$$$$  Define Parts and Materials  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$...>....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
$  

216
Rigid Sliding Block in Local Coordinate System

$ *SECTION_SOLID
$   sid   elform
   1   0
$
$ *SECTION_SHELL
$   sid   elform   shrf   nip   propt   qr/irid   icomp
   2
   1.0   1.0   1.0   1.0
$

$ Loading
$

$ 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
$

$ 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   0.000000E+00   0   0
   2   3.333333E-01   0.000000E+00   0.000000E+00   0.000000E+00   0   0
   3   6.666667E-01   0.000000E+00   0.000000E+00   0.000000E+00   0   0
   ... in total, 68 nodes defined
   66   1.000000E+00   0.000000E+00   -1.000000E+00   0.000000E+00   0   0
   67   0.000000E+00   1.000000E+00   -1.000000E+00   0.000000E+00   0   0
   68   1.000000E+00   1.000000E+00   -1.000000E+00   0.000000E+00   0   0
$

$ Solid Elements
$

$ *ELEMENT_SOLID
$   eid   pid   n1   n2   n3   n4   n5   n6   n7   n8
$ \text{*MAT\_RIGID} \\
\text{Rigid Sliding Block in Local Coordinate System} \\
\begin{array}{cccccccccccc}
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 \\
\end{array} \\
\ldots \text{in total, 27 solids defined} \\
\begin{array}{cccccccccccc}
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 \\
\end{array} \\
$ \\
\$\text{$$$$$ Shell Element - used to control the timestep}$ \\
\$ \\
\text{*ELEMENT\_SHELL} \\
\$ \\
\begin{array}{cccccccc}
\text{eid} & \text{pid} & \text{n1} & \text{n2} & \text{n3} & \text{n4} \\
1 & 2 & 65 & 67 & 68 & 66 \\
\end{array} \\
\$ \\
\text{*END}
Results:

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

state 11
view
*MAT_RIGID*
Rigid Sliding Block in Local Coordinate System
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/V_o) 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.
Soil and Foam Single Element

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/V_o) 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-s^2/in, in, s, lbf, psi, lbf-in
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$  Control Ouput
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*CONTROL_TERMINATION
$  endtim  endcyc  dtmin  endneg  endmas
   0.250
$
*CONTROL_ENERGY
$  hgen  rwen  slnten  rylen
     2   2
$
*DATABASE_BINARY_D3PLOT
$  dt/cycl  lcdt
     0.005
$
*DATABASE_BINARY_D3THDT
$  dt/cycl  lcdt
     0.001
$
*DATABASE_GLSTAT
$  dt/cycl  lcdt
     0.005
$
*DATABASE_ELOUT
$  dt/cycl  lcdt
     0.005
$
*DATABASE_HISTORY_SOLID
1
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$  Boundary Motion Conditions

222
$\textbf{*BOUNDARY_PRESCRIBED_MOTION_SET}
$ nid dof vad lcid sf vid
1 3 0 1 1.0 0
$
$\textbf{*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
$
$\textbf{*SET_NODE_LIST}
$ sid
$ 1
$ nid1 nid2 nid3 nid4 nid5 nid6 nid7 nid8
5 6 7 8
$
$\textbf{*PART}
$ pid sid mid eosid hgid adpopt
foam block
1 1 1
$
$\textbf{*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
$
$\textbf{*SECTION_SOLID}
$ sid elform
1
$\text{Soil and Foam Single Element} \\

$\text{Define Nodes and Elements}$ \\

$\text{8 nodes defined}$ \\

$\text{8 elements defined}$
Results:

Volumetric Crushing

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

Unloading Follows Loading Curve

```plaintext
taurus g=d3plot
phs2
elem 1 1 gather grid oset -1 2 etime 8 1 1
```
*MAT_SOIL_AND_FOAM*
Soil and Foam Single Element
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.
### *MAT_SPRING*

**Belted Dummy with Springs**

**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
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
*$CONTROL_TERMINATION
$ endtim endcyc dtmin endneg endmas
1.200E-01
$
*$CONTROL_CONTACT
$ slsfac rwpnal islchk shlthk penopt thkchg orien
2
$ usrstr usrfac nsbcs interm xpenen
$
*$CONTROL_TIMESTEP
$ dtinit acft isdo tslist dtms lctm erode mslst
0.000E+00 8.000E-01 0 0.000E+00 0.000E+00 0 0
$
$
$ DATABASE_BINARY_D3PLOT
$ dt/cycl lcdt
2.500E-03
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$ 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 0.000E+00
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$ Boundary Conditions
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
Belted Dummy with Springs

The base of the seat decelerates backwards relative to the dummy.

*BOUNDARY_PRESCRIBED_MOTION_SET

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<th>vad</th>
<th>lcid</th>
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*SET_NODE_LIST

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*DEFINE_CURVE

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<td>0.00000000E+00</td>
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<td>4.41500015E+01</td>
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<tr>
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Gravity

*LOAD_BODY_Z
**MAT_SPRING**

Belted Dummy with Springs

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*Contacts - Sliding Interfaces*

The segment sets associated with these contacts are located at the end of this file.

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|
*MAT_SPRING
Belted Dummy with Springs

*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

*

*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
MAT_SPRING
Belted Dummy with Springs

$ *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
$
$ *CONSTRINED_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
$
$
$$$$$$ Define Spring Orientation Vectors and Curves $$$$$$
$
...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$
$ *DEFINE_SD_ORIENTATION
$    vid  iop  xt  yt  zt  nid1  nid2
$      1    2  0.000E+00 0.000E+00 0.000E+00    100    229
$      2    2  0.000E+00 0.000E+00 0.000E+00    101    230
$      3    2  0.000E+00 0.000E+00 0.000E+00    102    231
... in total, 42 sd_orientation vectors defined
$
$
$$ Define Curves $$
$
*DEFINE_CURVE
$    lcid  sidr  scla  sclo  offa  offo
$      1    abcissa  ordinate
$      -1.71000004E+00  -5.38000000E+02
$      -7.0999979E-01  -8.47500000E+01
$      -6.80000007E-01  -7.76600037E+01
$      -6.60000026E-01  -7.10599976E+01
$      -5.8999974E-01  -5.36800003E+01
$      -5.00000000E-01  -4.05800018E+01
$      -3.8999986E-01  -2.99799995E+01
$      -2.0999997E-02  -4.65000010E+00
$      0.00000000E+00  0.00000000E+00
$      2.0999997E-02  4.65000010E+00
$      3.8999986E-01  2.99799995E+01
$      5.00000000E-01  4.05800018E+01
$      5.8999974E-01  5.36800003E+01
$
*MAT_SPRING
Belted Dummy with Springs

6.60000026E-01    7.10599976E+01
6.80000007E-01    7.76600037E+01
7.0999979E-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
*MAT_SPRING
Belted Dummy with Springs

part-22
  22  22  22  0
spring 101
  101  101  101
$
  ...  spring pid's 102-207 also defined here
$
spring 208
  208  208  208
$
$$$$$$  Materials
$
$
$$$$  Rigid Materials
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
1  4.064E+03 4.000E+08 3.000E-01 0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
  ...  mat_rigid mid's 2-14 also defined here
$
*MAT_RIGID
$      mid        ro         e        pr         n    couple         m     alias
15 2.000E+03 4.000E+08 3.000E-01
0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
$
$
$$$$  Elastic Materials
$
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
16 4.646E+03 4.000E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
17 4.646E+03 4.000E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
18 4.646E+03 4.000E+09 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
19 4.646E+03 4.000E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
20 2.000E+03 4.100E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
21 2.000E+03 4.100E+08 3.000E-01
*MAT_ELASTIC
$      mid        ro         e        pr        da        db         k
22 4.000E+03 2.000E+08 3.000E-01
$
$
$$$$$$  Nonlinear Elastic Spring Materials
$
*MAT_SPRING_NONLINEAR_ELASTIC

234
Belted Dummy with Springs

*MAT_SPRING

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
$
$
$$  Shell Sections
$
*$SECTION_SHELL

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

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
*MAT_SPRING
Belted Dummy with Springs

0.000E+00  0.000E+00
$
  ...

... spring-damper sid’s 102-207 also defined here
$
$
*SECTION_DISCRETE
  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-01-1.3286990896E-02  5.876007080E-01       0       0
  2-2.475307435E-01-1.784761624E-03  5.820254087E-01       0       0
  3-2.491816529E-01-1.108985014E-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       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, 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
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$
$$ Segment sets for the contacts defined previously.
$$

236
$\ldots\ldots1\ldots\ldots2\ldots\ldots3\ldots\ldots4\ldots\ldots5\ldots\ldots6\ldots\ldots7\ldots\ldots8$

$\text{*SET_SEGMENT}$

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<td>1787</td>
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... in total, 22 segment sets defined for the contacts

$\text{*END}$
**MAT_SPRING**  
Belted Dummy with Springs

Results:

- taurus g=d3plot
- 19
- rx -90 center view

![Belted Dummy with Springs](image)

- state 49
- center view

![Belted Dummy with Springs](image)
**MAT_TRANSVERSELY_ANISOTROPIC**

Rectangular Cup Drawing

**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
$

*CONTROL_TERMINATION
$ endtim endcyc dtmin endeng endmas
  0.015
$

*CONTROL_CONTACT
$ slsfac rwpnal islchk shlthk penopt thkchg orien
  0.1  0.0  1  2  0  2  2
$ usstr usrfac nsbcs interm xpenen
  0  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  1  0.0
$

*CONTROL_SHELL
$ wrpang itrist irnxx istudp 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
### *MAT_TRANSVERSELY_ANISOTROPIC*

#### Rectangular Cup Drawing

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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

```plaintext
$ cmpflg ieverp beamip
0       1       0
$
```

```plaintext
*DATABASE_GLSTAT
0.0001
*
```

```plaintext
*DATABASE_RCFORC
0.0001
*
```

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$  Define Curves
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

```plaintext
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
```

```plaintext
*DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
1         0       1.0       1.0   2.0E-03       0.0
$
```

```plaintext
$ 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
$
```

```plaintext
*$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
$
```

```plaintext
*$DEFINE_CURVE
$     lcid      sidr      scla      sclo      offa      offo
3
$ absc  ordin
0.0, 0.0
1.0, 0.413E05
$
```

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**MAT_TRANSVERSELY_ANISOTROPIC**

Rectangular Cup Drawing

```
$ *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

*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_TRANSVERSELY_ANISOTROPIC
Rectangular Cup Drawing

$ *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/al  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/al  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
  1.000E+03  1.000E+00  1.000E+00  1.000E+00
$

$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$  Define Contacts
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$ 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  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
*MAT_TRANSVERSELY_ANISOTROPIC*

Rectangular Cup Drawing

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</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>0.80</td>
<td>1.00</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*CONTACT_ONE_WAY_SURFACE_TO_SURFACE*

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<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>0.80</td>
<td>1.00</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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**Boundary Conditions**

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</thead>
<tbody>
<tr>
<td>10061</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10122</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>

... in total, 101 SPC's defined

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<tbody>
<tr>
<td>10059</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10060</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
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**Loading**

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</thead>
<tbody>
<tr>
<td>30001</td>
<td>5</td>
<td>-1.00E+00</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30002</td>
<td>5</td>
<td>-1.00E+00</td>
<td>0.0</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

... in total, 448 shell element loads defined

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</thead>
<tbody>
<tr>
<td>30447</td>
<td>5</td>
<td>-1.00E+00</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30448</td>
<td>5</td>
<td>-1.00E+00</td>
<td>0.0</td>
<td></td>
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</tbody>
</table>

**Define Nodes and Elements**

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</thead>
<tbody>
<tr>
<td>20001</td>
<td>6.70000000E+01</td>
<td>1.624058654E-14</td>
<td>-1.00000000E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20002</td>
<td>6.734069807E+01</td>
<td>2.462506303E-10</td>
<td>-7.41197155E+00</td>
<td></td>
<td></td>
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... in total, 4266 nodes defined

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</tr>
</thead>
<tbody>
<tr>
<td>12500</td>
<td>1.666667211E+00</td>
<td>8.500000000E+00</td>
<td>1.000000000E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
*MAT_TRANSVERSELY_ANISOTROPIC
  Rectangular Cup Drawing

  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
$$
  nl      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
*RIGIDWALL_GEOMETRIC_SPHERE_MOTION

Rigid Wall Sphere Impacts a Plate

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 × 40 × 2 mm³. 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 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
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  Control Output
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  Control TERMINATION
$   endtim  endcyc  dtmin  endneg  endmas
   .5000E-3
$
*CONTROL_HOURGLASS
$   ihq  qh
   4
$
$  DATABASE_BINARY_D3PLOT
$   dt  lcdt
   0.0200E-3
$
*DATABASE_EXTENT_BINARY
$   neiph  neips  maxint  strflg  sigflg  epsflg  rltflg  engflg
   l
$   cmpflg  ieverp  beamip
$
*DATABASE_RWFORC
$   dt
   0.005e-4
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  Rigidwalls
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$  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
*RIGIDWALL_GEOMETRIC_SPHERE_MOTION
Rigid Wall Sphere Impacts a Plate

1 1 0.0 0.0 -1.0

*DEFINE_CURVE
lcid sidr scla scl0 offa offo
1
absccisa ordinate
0.0 0.0
0.0005 15.0

*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
2 2.0 2.0 2.0 2.0

*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

*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

$
Results:

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

phs3
rwforc
normal
```
*RIGIDWALL_GEOMETRIC_SPHERE_MOTION*
Rigid Wall Sphere Impacts a Plate
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 $10 \times 10 \times 2 \text{ mm}^3$. 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.
**RIGIDWALL_PLANAR**  
Rotating Shell Strikes Rigid Wall

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  
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$  
$$$$$$$ Control Ouput  
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$  
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8  
$  
*CONTROL_TERMINATION  
$   endtim    endcyc     dtmin    endneg    endmas  
2.000E-04  
$  
*CONTROL_ENERGY  
$   hgen      rwen    slnten     rylen  
2        2  
$  
$  
*DATABASE_BINARY_D3PLOT  
$   dt      lcdt  
1.000E-05  
$  
*DATABASE_BINARY_D3THDT  
$   dt      lcdt  
2.000E-03  
$  
*DATABASE_GLSTAT  
$   dt  
4.0e-06  
$  
*DATABASE_NODOUT  
$   dt  
4.0e-06  
$  
*DATABASE_HISTORY_NODE  
$   i         i         i         i         i         i         i         i  
12        13       101  
$  
*DATABASE_RWFORC  
$   dt  
4.0e-06  
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$  
$$$$$$$ Rigidwalls  
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$  
$  
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8  
$
The nodes in set 1 (nodes of the moving shell) are prevented from penetrating the rigid wall.

*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

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

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
*RIGIDWALL_PLANAR
Rotating Shell Strikes Rigid Wall

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+00 0.000000000E+00 0.000000000E+00 7 0
3 2.000000000E+00 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 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

phas3
rwforc
normal
*RIGIDWALL_PLANAR*

Rotating Shell Strikes Rigid Wall
**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.
**RIGIDWALL_PLANAR_FORCES**

Cube Rebounding

List of LS-DYNA input deck:

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

260
*RIGIDWALL_PLANAR_FORCES
Cube Rebounding

$\ldots\ldots1\ldots\ldots2\ldots\ldots3\ldots\ldots4\ldots\ldots5\ldots\ldots6\ldots\ldots7\ldots\ldots8$

$\text{*RIGIDWALL\_PLANAR\_FORCES}$

$\text{nsid nsidex boxid}$

\begin{verbatim}
  1 0 0
\end{verbatim}

$\text{xt yt zt xh yh zh fric}$

\begin{verbatim}
  20.0 20.0 0.0 20.0 20.0 100.0 0.000
\end{verbatim}

$\text{soft ssid nid1 nid2 nid3 nid4}$

\begin{verbatim}
  10 0 1 4 13 16
\end{verbatim}

$\text{SET\_NODE\_LIST}$

$\text{sid}$

\begin{verbatim}
  1
  201 202 203 204 205 206 207 208 209
\end{verbatim}

$\text{INITIAL\_VELOCITY}$

$\text{nsid nsidex boxid}$

\begin{verbatim}
  1
  0 0 -100000.0
\end{verbatim}

$\text{DEFINE\_BOX}$

$\text{boxid xmm xmx ymn ymx zmn zmx}$

\begin{verbatim}
  1 14.9 25.1 14.9 25.1 9.0 21.0
\end{verbatim}

$\text{PART}$

$\text{pid sid mid eosid hgidi adpopt}$

\begin{verbatim}
  wall-display
  1 1 1
  cube
  2 2 2 0 0 0
\end{verbatim}

$\text{MAT\_ELASTIC}$

$\text{mid ro e pr da db}$

\begin{verbatim}
  1 2.00e-8 100000.0 0.300
\end{verbatim}

$\text{MAT\_ELASTIC}$
Cube Rebounding

$ 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
$

$ *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
$

$ 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:

\texttt{taurus g=d3plot}
\texttt{19}
\texttt{rx -80 view}

\texttt{phs3 glstat}
\texttt{otxt Kinetic and Stonewall Energy}
\texttt{oset 0 5.25e4 kinetic over stonewall}
*RIGIDWALL_PLANAR_FORCES*
Cube Rebounding
**RIGIDWALL_PLANAR_MOVING**

Symmetric Crush Tube

**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.
**RIGIDWALL_PLANAR_MOVING**
Symmetric Crush Tube

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
$  
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$  Control Ouput
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$...
$  *CONTROL_TERMINATION
$  endtim    endcyc     dtmin    endneg    endmas
15.01         0       0.0       0.0       0.0
$  
$  *CONTROL_ENERGY
$  hgen      rwen    slnten     rylen
2         2         2
$  
$  *CONTROL_OUTPUT
$  npopt    neecho    nrefup    iaccop    opifs    ipnint    ikedit
1         3
$  
$  *DATABASE_BINARY_D3PLOT
$  dt       lcdt
1.0
$  
$  *DATABASE_EXTENT_BINARY
$  neigh     neips    maxint    strflg    sigflg    epsflg    rltflg    engflg
  cmpflg    ieverp    beamip
1
$  
$  *DATABASE_BINARY_D3THDT
$  dt       lcdt
999999
$  
$  *DATABASE_GLSTAT
$  dt
0.1
$  
$  *DATABASE_MATSUM
$  dt
0.1
$  
$  *DATABASE_NODOUT
$  dt
0.1
$ *DATABASE_HISTORY_NODE
$    id1  id2  id3  id4  id5  id6  id7  id8
$    99999  414  486
$
$ *DATABASE_RWFORC
$    dt  0.1
$
$ *DATABASE_SLEOUT
$    dt  0.1
$
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$$$  Define Contacts - Sliding Interfaces
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ $ *CONTACT_AUTOMATIC_SINGLE_SURFACE
$    ssid  msid  sstyp  mstyp  sboxid  mboxid  spr  mpr
$    0
$ $ Equating ssid to zero means that all segments are included in the contact
$ $    fs  fd  dc  vc  vdc  penchk  bt  dt
$    0.08  0.08
$ $    sfs  sfm  sst  mst  sfst  sfmt  fsf  vsf
$ $ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$$$  Define Rigidwalls
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ $ *RIGIDWALL_PLANAR_MOVING_FORCES
$    nsid  nsidex  boxid
$    0  0  0
$ $    xt  yt  zt  xh  yh  zh  fric
$    0.0  0.0  274.0  0.0  0.0  0.0  1.0
$ $ $ sw mass  sw vel
$ $    800.000  8.94000
$ $    soft  ssid  node1  node2  node3  node4
$    0  0  99999
$ $ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $$$$$$  Define Parts and Materials
$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$ $ *PART
*RIGIDWALL_PLANAR_MOVING
Symmetric Crush Tube

```plaintext
corner1

$ pid sid mid eosid hgid grav adpopt
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 lcis lcse
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
$

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

*NODE
$ nid x y z tc rc
99999 0.0 0.0 274.0 0 0
1 -5.00000000E+01 -4.80000000E+01 0.0000000000E+00 0 0
2 -4.16667000E+01 -4.80000000E+01 0.0000000000E+00 0 0
...

in total, 519 nodes defined
```

268
*RIGIDWALL_PLANAR_MOVING
Symmetric Crush Tube

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
$
<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>752</td>
<td>1</td>
<td>547</td>
<td>552</td>
<td>553</td>
<td>553</td>
</tr>
<tr>
<td>753</td>
<td>1</td>
<td>553</td>
<td>548</td>
<td>547</td>
<td>547</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

... in total, 467 shells defined

640 1 710 711 716 715
641 1 711 485 487 716
$
*END
*RIGIDWALL_PLANAR_MOVING*
Symmetric Crush Tube

Results:

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

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

![Graph](image1)

![Graph](image2)
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:

*SECTION_SHELL
Fuse plate in tension exhibits hourglassing

Fuse plate being pulled apart 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

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$ Controls Output

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

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8

*CONTROL_TERMINATION
  endtim  endcyc  dtmin  endneg  endmas
  10.00

*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
**Fuse Plate in Tension Exhibits Hourglassing**

\$ Spotweld the fuse plate to the post flanges. 
\$

\*CONSTRANDED_SPOTWELD 
\$  
\$  

\$ Boundary and Loading Conditions 
\$

\$ Define Parts and Materials 
\$
*SECTION_SHELL
Fuse Plate in Tension Exhibits Hourglassing

postweb
fuseplat

$ $$ $ Materials $ $ $MAT_PIECEWISE_LINEAR_PLASTICITY $...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
mid ro e pr sigy etan epf tdel
1 0.783E-05 2.000E+02 0.3 2.070E-01 7.500E-01
$ Cowper/Symonds Strain Rate Parameters $ c p lcsp lcsp
40 5 $ Plastic stress/strain curve 0.000E+00 8.000E-02 1.600E-01 4.000E-01 9.900E+01
2.070E-01 2.500E-01 2.750E-01 2.899E-01 3.000E-01
$ $ $$ $ 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 6 $ t1 t2 t3 t4 nloc 4.7625E+00 4.762E+00 4.762E+00 4.762E+00
$ $$ Define Nodes and Elements $$ $$ $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

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>487</td>
<td>1</td>
<td>647</td>
<td>123</td>
<td>501</td>
<td>501</td>
</tr>
<tr>
<td>488</td>
<td>1</td>
<td>647</td>
<td>501</td>
<td>653</td>
<td>653</td>
</tr>
</tbody>
</table>

... in total, 436 shells defined.

<table>
<thead>
<tr>
<th>eid</th>
<th>pid</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>387</td>
<td>3</td>
<td>499</td>
<td>496</td>
<td>289</td>
<td>497</td>
</tr>
<tr>
<td>388</td>
<td>3</td>
<td>422</td>
<td>499</td>
<td>497</td>
<td>287</td>
</tr>
</tbody>
</table>

*END*
*SECTION_SHELL
Fuse Plate in Tension Exhibits Hourglassing

Results:

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

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image1}
\caption{Fuse Plate Being Pulled in Tension Exhibits Hourglassing}
\end{figure}

s 10
m 3
center view

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image2}
\caption{Fuse Plate Being Pulled in Tension Exhibits Hourglassing}
\end{figure}
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.
*SECTION_SOLID
Breaking Post Exhibits 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
$    $$$  Control Ouput
$    $$$  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
$    $    neigh  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
Breaking Post Exhibits Hourglassing

$ 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
$sid$ msid sstyp mstyp sboxid mboxid spr mpr
0
$sf$ 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
$ $$

$ $$$ Define Parts and Materials
$ $$
*SECTION_SOLID

Breaking Post Exhibits Hourglassing

$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8$
$
$$\text{Part} \ 3 \ \text{shell: beam}$$
$
$$\text{Part} \ 4 \ \text{solid: lower_post}$$
$
$$\text{Part} \ 5 \ \text{solid: upper_post}$$
$
$
*$\text{PART}$
$\begin{array}{ccccccccc}
\text{pid} & \text{sid} & \text{mid} & \text{eosid} & \text{hgid} & \text{grav} & \text{adpopt} \\
\text{bumper} & 3 & 1 & 1 & & & & \\
\text{lower\_post} & 4 & 2 & 2 & & & & \\
\text{upper\_post} & 5 & 2 & 3 & & & & \\
\end{array}$
$
$$\text{Materials}$$
$
$$\text{Bumper - Rigid, constrained to translate only in the x-direction}$$
$
*$\text{MAT\_RIGID}$
$\begin{array}{cccccccc}
\text{mid} & \text{ro} & \text{e} & \text{pr} & \text{n} & \text{couple} & \text{m} & \text{alias} \\
1 & 0.143\times10^{-2} & 200.0 & 0.33 & & & & \\
\end{array}$
$
$$\text{Post - the lower portion is softer and fails sooner than the upper portion}$$
$
*$\text{MAT\_PIECEWISE\_LINEAR\_PLASTICITY}$
$\begin{array}{cccccccc}
\text{mid} & \text{ro} & \text{e} & \text{pr} & \text{sigy} & \text{etan} & \text{eppf} & \text{tdel} \\
2 & 0.499\times10^{-6} & 11.37 & 0.32 & 0.0468 & & 0.11 & \\
\end{array}$
$
$$\text{Plastic stress/strain curve}$$
$\begin{array}{cccc}
0.0000 & 0.2500 & 0.0468 & 0.0470 \\
\end{array}$
$
$$\text{Post - the lower portion is softer and fails sooner than the upper portion}$$
$
*$\text{MAT\_PIECEWISE\_LINEAR\_PLASTICITY}$
$\begin{array}{cccccccc}
\text{mid} & \text{ro} & \text{e} & \text{pr} & \text{sigy} & \text{etan} & \text{eppf} & \text{tdel} \\
3 & 0.499\times10^{-6} & 110.37 & 0.32 & 0.0468 & & 0.25 & \\
\end{array}$
$
$$\text{Plastic stress/strain curve}$$
$\begin{array}{cccc}
0.0000 & 0.2500 & 0.0468 & 0.0470 \\
\end{array}$
$
$$\text{Sections}$$
$
*$\text{SECTION\_SHELL}$
$\begin{array}{ccccccccccc}
\text{sid} & \text{elform} & \text{shrf} & \text{nip} & \text{propt} & \text{qr/irid} & \text{icomp} \\
\end{array}$
Breaking Post Exhibits Hourglassing

---

1 | 2 | 3.0
---|---|---
1.54 | 1.54 | 1.54 | 1.54

---

*SECTION_SOLID

$ sid elform
2 1

---

*$SECTION_SOLID

---

Define Nodes and Elements

---

**NODE

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<th>z</th>
<th>tc</th>
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<td>0</td>
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<tr>
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<td>1.25715000E+03</td>
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... in total, 529 nodes defined

---

Solid Elements

---

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... in total, 252 solids defined

---

Shell Elements

---

**ELEMENT_SHELL

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<td>3</td>
<td>33</td>
<td>49</td>
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... in total, 70 shells defined

---

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:

```plaintext
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
```
Acknowledgments

N. Brannberg, L. Fredriksson and A. Gokstorp translated the description of many CADFEM examples from German to English.

Several of the new examples in the 1997 edition of this examples manual were constructed by starting with models obtained from Gene Paulsen (former Graduate student at U. Nebraska), John Gee (Cray Research), and Brad Maker (LSTC).
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