Workshop
Best Practice in Crash Analysis and LS-DYNA Tools

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Agenda

- Useful keyword – settings
- General recommendations for LS-DYNA models
- LS-DYNA tools

Useful keyword – settings

***CONTROL_ACCURACY, INN=2 / 4**

Card 1	1	2	3	4	5	6	7	8
Variable	OSU	INN	PIDOSU					
Type	I	I	I					
Default	0 (off)		optional					

- Invariant node numbering for shell and solid elements
- INN=2: On for shell and thick shell elements
- INN=4: as INN=2 but for solids as well (for anisotropic materials only)
- Affects the choice of the local element shell coordinate system
- Element forces are nearly independent of node sequencing
- Stable calculations over long time periods are achievable

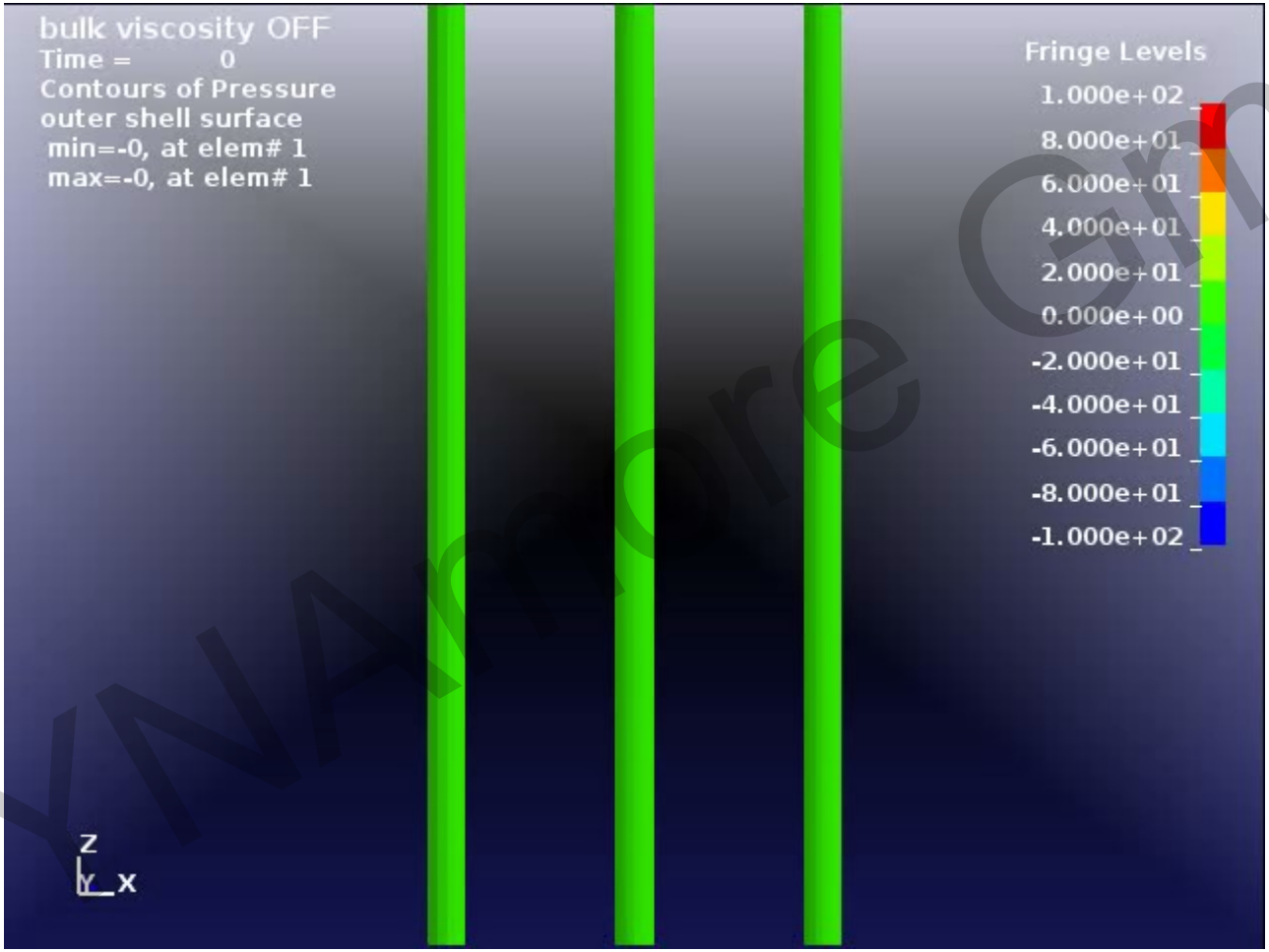
Useful keyword – settings

*CONTROL_BULK_VISCOSITY, TYPE=-1/-2

Card 1	1	2	3	4	5	6	7	8
Variable	Q1	Q2	TYPE	BTYPE				
Type	F	F	I	I				
Default	1.5	.06	1	0				

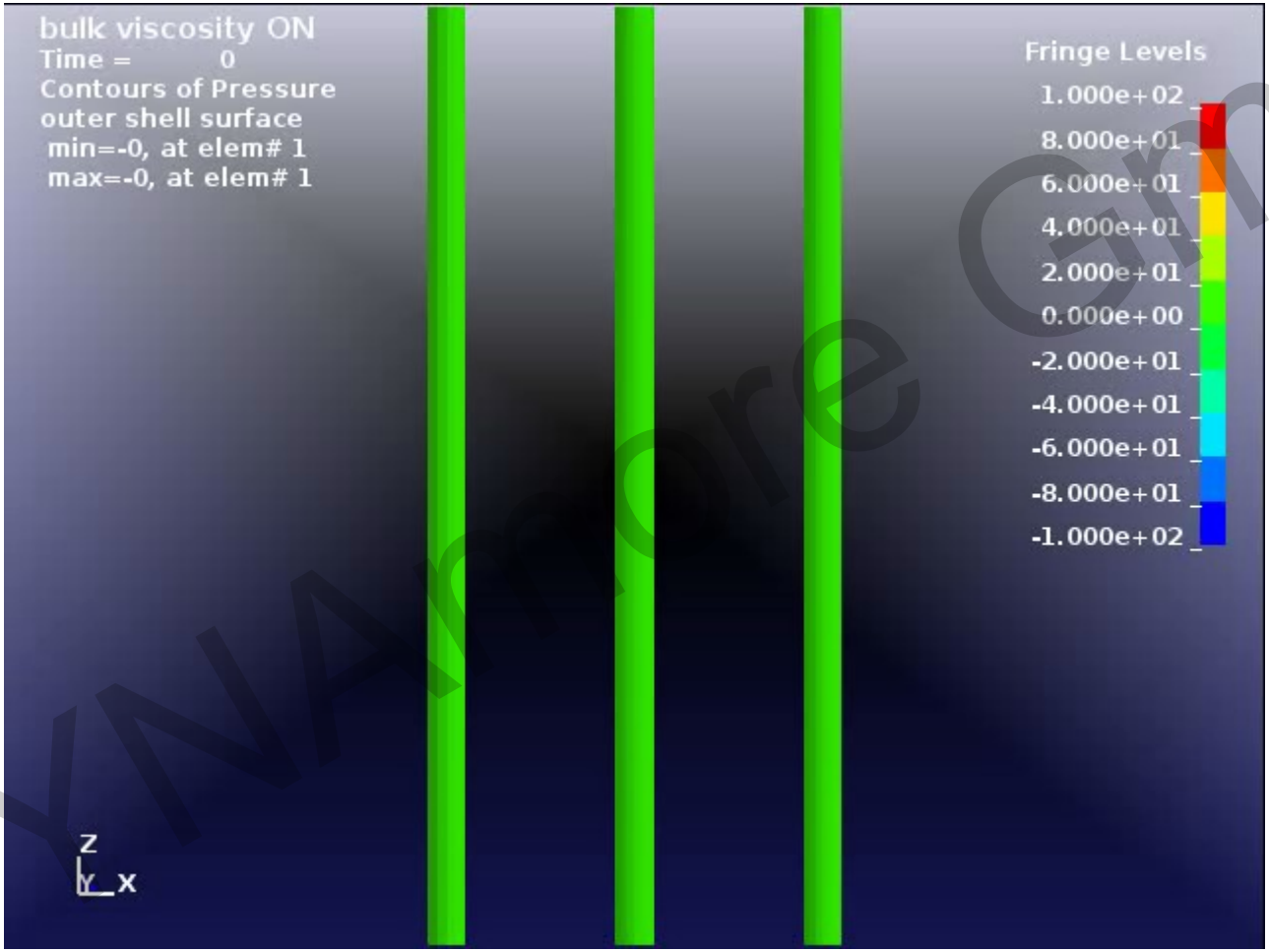
- Important for proper shock wave diffusion of shells
- Leads for many load case to reduction of variance
- TYPE= -2 ≙ -1 but include corresponding energy to „internal energy“

*CONTROL_BULK_VISCOSITY, TYPE=-1/-2



No bulk viscosity

*CONTROL_BULK_VISCOSITY, TYPE=-1/-2

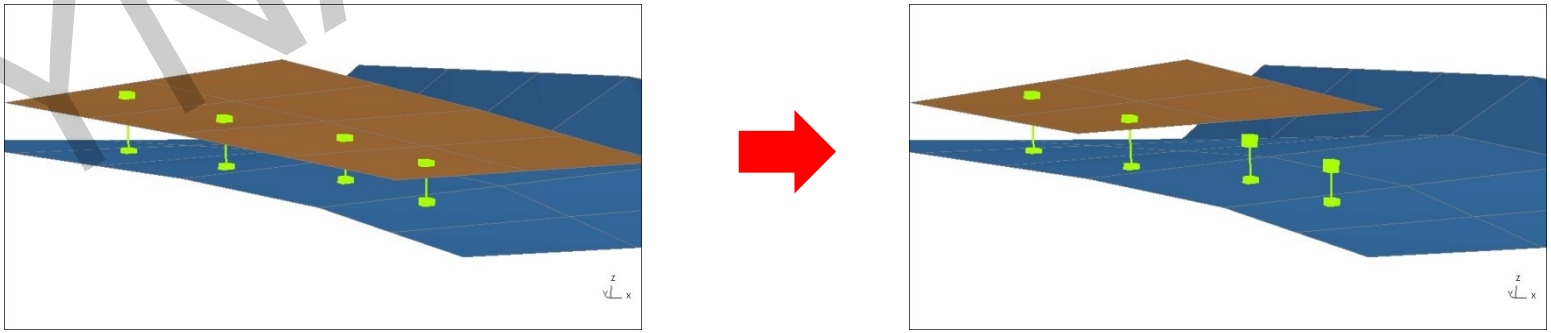


With bulk viscosity

*CONTROL_CONTACT, SPOTDEL=1

Card 4	1	2	3	4	5	6	7	8
Variable	IGNORE	FRCENG	SKIPRWG	OUTSEG	SPOTSTP	SPOTDEL	SPOTHIN	
Type	I	I	I	I	I	I	F	
Default	0	0	0	0	0	0	inactive	

- If master segment fails, spot weld defined by *MAT_SPOTWELD is deleted also
- Otherwise remaining spotweld can lead to instabilty, e.g. oscillation because sudden release of elastic energy



Useful keyword – settings

***CONTROL_HOURGLASS, IHQ=8**

Card 1	1	2	3	4	5	6	7	8
Variable	IHQ	QH						
Type	I	F						
Default		0.1						

- Additonal warping-stiffness for fully integrated shell elements (elform=16)
- For any other types of shells, LS-DYNA set IHQ=5
- Alternatively use *HOURGLASS for individual parts

*CONTROL_OUTPUT, IACCOP=1

Card 1	1	2	3	4	5	6	7	8
Variable	NPOPT	NEECHO	NREFUP	IACCOP	OPIFS	IPNINT	IKEDIT	IFLUSH
Type	I	I	I	I	F	I	I	I
Default	0	0	0	0	0.	0	100	5000

- Average nodal accelerations output to `nodout` and `d3thdt`
- Strongly recommended for direct evaluaton of nodal accelerations

*CONTROL_OUTPUT, IERODE=1

Card 2	1	2	3	4	5	6	7	8
Variable	IPRTF	IERODE	TET10	MSGMAX	IPCURV	GMDT	IP1DBLT	EOCS
Type	I	I	I	I	I	F	I	I
Default	0	0	2	50	0	0.	0	0

- Eroded internal and kinetic energies are output into the `matsum` file
- In addition, determination of mass for all elements defined by *ELEMENT_MASS and added as part-ID „0“ into `matsum`

Useful keyword – settings

***CONTROL_OUTPUT, MSGMAX=99000**

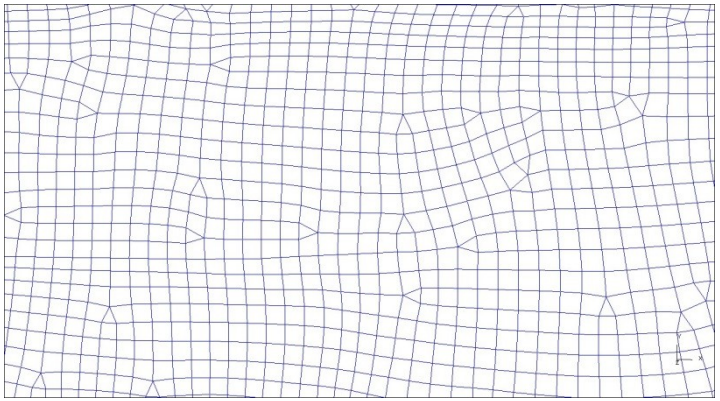
Card 2	1	2	3	4	5	6	7	8
Variable	IPRTF	IERODE	TET10	MSGMAX	IPCURV	GMDT	IP1DBLT	EOCS
Type	I	I	I	I	I	F	I	I
Default	0	0	2	50	0	0.	0	0

- Write all warnings into message files
- Otherwise important warnings may be missed, e.g. für untied spotwelds or initial penetrations through contact definitions

*CONTROL_SHELL, ESORT=1

Card 1	1	2	3	4	5	6	7	8
Variable	WRPANG	ESORT	IRNXX	ISTUPD	THEORY	BWC	MITER	PROJ
Type	F	I	I	I	I	I	I	I
Default	20.	0	-1	0	2	2	1	0

- Automatic sorting of triangular shell elements to treat degenerated quadrilateral shell elements
- Meaningless, if *SECTION_SHELL is defined with correct element type



*CONTROL_SHELL, BWC=0 (statt 1)

Card 1	1	2	3	4	5	6	7	8
Variable	WRPANG	ESORT	IRNXX	ISTUPD	THEORY	BWC	MITER	PROJ
Type	F	I	I	I	I	I	I	I
Default	20.	0	-1	0	2	2	1	0

- Belytschko-Wong-Chiang warping stiffness should never be enabled for entire model, because of possible disturbance of the solution
- If it is needed for certain parts, activation with shell type 10 in *SECTION_SHELL or even better with shell type 16 and IHQ=8
- Important to know: BWC=1 alters the behaviour of validated models such as barriers and dummies incorporated via *INCLUDE

*CONTROL_SHELL, NFAIL4=1

Card 4	1	2	3	4	5	6	7	8
Variable	NFAIL1	NFAIL4	PSNFAIL	KEEPCS	DELFR	DRCPSID	DRCPRM	INTPERR
Type	I	I	I	I	I	I	F	
Default	inactive	inactive	0	0	0	0	1.0	

- Check and delete highly distorted fully integrated shell elements during simulation due to negative Jacobians
- Without this option, non physical effects may occur or possibly error terminations

*CONTROL_SOLD, ESORT=1

Card 1	1	2	3	4	5	6	7	8
Variable	ESORT	FMATRX	NIPTETS	SWLOCL	PSFAIL	T10JTOL		
Type	I	I	I	I	I	F		
Default	0	0	4	2	0	0.		

- Automatic sorting of tetrahedron and pentahedron elements to treat degenerated tetrahedron and pentahedron elements
- Meaningless, if *SECTION_SOLID is defined with correct element type

*CONTROL_SOLUTION, ISNAN=1

Card 1	1	2	3	4	5	6	7	8
Variable	SOLN	NLQ	ISNAN	LCINT				
Type	I	I	I	I				
Default	0	0	0	100				

- Each cycle forces and moments are checked for „NaN“
- Therefore problems may be detected early and affected nodes are identified
- Otherwise simulation can run some cycles with „NaN“ until error termination occurs
- Detecting the reasons afterwards, is usually very difficult

Useful keyword – settings

***CONTROL_SOLUTION, LCINT=1001**

Card 1	1	2	3	4	5	6	7	8
Variable	SOLN	NLQ	ISNAN	LCINT				
Type	I	I	I	I				
Default	0	0	0	100				

- Enlarge number of points in load curve for materials
- Additonal memory usage is insignificant
- Load curve fits better to defined load curve
- Use uneven number in order to ensure that curve goes through (0;0) in case of symmetrical load curves, e.g. tensile or compressive behavior

Useful keyword – settings

***CONTROL_MPP_IO_NODUMP**

There are no parameters for this keyword.

- Suppresses the output of all dump files and full restart files
- If needed, press sense switches „sw1“ or „sw3“ during simulation to write dump file

Useful keyword – settings

*DATABASE_FORMAT, IBINARY=1

Card 1	1	2	3	4	5	6	7	8
Variable	IFORM	IBINARY						
Type	I	I						
Default	0	0						
Remarks	1	2						

- Output `d3plot` in 32 bit format
- Double-precision write 64 bit naturally, which can not be handled by FEMZIP or DYNAmore tool „plotcprs“

Material

- Instead of pure elastic materials, use elasto-plastic material models

  Using pure elastic material models or material models with very high yield stresses could cause shooting nodes,
  because the stored internal energy could be released rapidly.
  This could influence the behavior of the whole model or terminates the simulation due to NaN.
- Use realistic material parameters – artificially increased parameters to model body stops or constraints are not recommended
- Define smoothed stress-strain curves
- For materials with strain rate sensitivity enable viscoplastic formulaton (VP=1)

  VP=0 often produces less smooth strain rates
- For VP=1, load curves have to be defined with identical min/max values for strain values and must not cross when extrapolated

Contact

- Always use contact damping (VDC=20 - 40%)
- For SOFT=1 define contact stiffness DTSTIF=0.6 - 1.0 µs (optional contact card C), unless time step is inside this range
- For SOFT=2 smaller DTSTIF possible (around 0.4 µs)
- The aim is to avoid too high contact stiffnesses
- Instead of solid elements defined with failure and covered with null shells, use SLDTHK (optional contact card B)
- No MAT_NULL contact beams on edges with failure. Alternatively use SOFT=2, SBOPT=3, DEPTH=3
- Reduce contact definitions / merge contact definitions when possible
- Avoid mid-face penetrations
- Define IGNORE=2 and check the warning messages, allow small values only

Contact

- For penalty based tied contact use option „_BEAM_OFFSET“ or TIEDID=1 (optional contact card D) > smoother contact behaviour
- Define only one constraint tied contact, for all connection elements (spotweld beams or hexahedrons, glued hexahedron elements, etc.) to overcome conflicting constraint problems
- Include only these nodes on slave side in tied contacts which have to be tied. Otherwise too many useless LS-DYNA warnings occur
- Check, if all slave nodes of the tied contacts are tied to a master segment
- For shell failure care must be taken that never a single IP may remain. As a consequence, a failure criterion with NUMINT < NIP should be chosen (e.g. *MAT_123 instead of MAT_24)

General

- For very short beams use *MAT_SPOTWELD
- Check for all kind of conflicting constraints
- Simple model check: run a few hundred/thousand cycles without initial velocities > model must remain stable
- Check noise (e.g. by velocity field) after initial loads are applied (e.g. pre-stressed bolts or screws, gravity loading, tires with pressure, others ...)
- Check energies for plausibility (`glstat`, `matsum`)
- define *Rayleigh* damping, *DAMPING_PART_STIFFNESS, COEF=0.05, for parts dominated by elastic deformations or for the whole model
- Check warning messages

DYNAmore tools for working with LS-DYNA

- OS: Linux / Windows
- Programming language: Perl and Fortran
- Version: tool -v
- Help: tool -h
- Annually license (IP-address or IP-range)
- Free of charge for LS-DYNA customers
- Order: www.dynamore.de

Tools to compress, control and convert

- **plotcprs2** `d3plot-` reduce, merge, convert data
- **d3plot-head2** modify title in `d3plot` file
- **kin2plot** convert Madymo-file (kin3) to LS-DYNA format
- **check-binout** fix `binout` if corrupt

plotcprs2 -h

```
 plotcprs compresses LS-DYNA plotfiles by:
 - optional eliminating result data on plot states
 - optional selection of parts or part ranges
 - optional coordinate box for elements to select
 - optional transformation of nodal results
    onto a moving local system
 - optional conversion of units for nodal results
 and any combination of these features -
 result files may optionally be merged or splittet

usage: plotcprs [options]

options:
-g plotfile    LS-DYNA binary plot geometry data file
                 (default: d3plot)
-o prefix      prefix name for resulting plotfile
                 (default: "cpr_")
-t title       title/heading on resulting plotfile
                 (default: no change to title text)
-------------------------------------------------------------
-m part-file   file name for list of parts to be in/excluded
                 (default: all parts are included)
                 syntax of part-file:
                 -id       excludes part with id
                  id       includes part with id
                  id1-id2  includes parts from id1-id2
-excl          parts in part-file are excluded (option -m)
                 (default: parts are included)
-box boxfile   file name for min/max coordinate range (box)
                 (default: all elements are included)
                 syntax of box-file:
                 xmin=value, ... , zmax=value
                 (format and order are arbitrary)
-------------------------------------------------------------
-rel ref-file  file with three nodes that define ref.-system
                 dis/vel/acc are transformed into ref-system
-iv            transform velocities as intrusion velocities
               relativ to the reference system defined above
-troff <node>  translational offset by coordinates of <node>
-troff <file>  translational offset defined in <file>
-------------------------------------------------------------
-velo          write nodal velocities
-acc           write nodal accelerations
-temp          write nodal temperatures
-stress        write stress tensor  (shell)
-vmises        write v.Mises stress as extra history variable
               (overrides "-stress" option)
-triax         write ratio p/vMises as extra history variable
-plast         write plastic strain (shell)
-shist         write extra shell history variables (shell)
-max           write max. value of all int-points (shell)
               (for "-stress","-vmises", "-plast","-shist")
                 (default: all int-points are written)
-thick         write thickness and internal energy (shell)
-beam          write all beam element results
-solid         write all solid element results
-shell         write all shell element results
-sph           write all sph element results
-cpm           write all corpuscular particle results
-elem          write all element data ("-beam -solid -shell")
-full          write all result data (useful for -m option)
-------------------------------------------------------------
-uc ##         unit conversion type on nodal results
               (1) m-s-kg; (2) mm-s-t;  (3) mm-ms-kg
               eg: "-uc 21" converts from (2) to (1)
-mirr x|y|z    mirror nodal data in x|y|z-direction in origin
               eg: "-mirr xy"
-------------------------------------------------------------
-merge         merge resulting states into ONE plotfile
-split         split resulting states on seperate plotfiles
-------------------------------------------------------------
-info          gives information about compression factor
-check         check plotfiles and compression factor
-list          list content of plotfile
-v             gives version number
-h             give this help on screen
```

Beispiel: plotcprs2 -info

```
title of plotfile      : Tutorial 5 Front crash
compression factor:    87.75 %   per state
```

Beispiel: plotcprs2 -check

```
title of plotfile      : Tutorial 5 Front crash
state:    1  time: 0.000000E+00    d3plot
state:    2  time: 4.999050E+00    d3plot
state:    3  time: 9.999450E+00    d3plot
...
state:   13  time: 5.999940E+01    d3plot
state:   14  time: 6.499979E+01    d3plot
state:   15  time: 6.999885E+01    d3plot
state:   16  time: 7.499924E+01    d3plot01
state:   17  time: 7.999964E+01    d3plot01
state:   18  time: 8.499870E+01    d3plot01
...
state:   30  time: 1.449994E+02    d3plot01
state:   31  time: 1.499998E+02    d3plot02
state:   32  time: 1.500012E+02    d3plot02
compression factor:    87.75 %   per state
```

Beispiel: plotcprs2 -list

```
title of plotfile      : Tutorial 5 Front crash
format of plotfile     : lstc
number of materials    :  371
    solid materials    :  74
    beam  materials    :  31
    shell materials    :  266
  t-shell materials    :  0
    rigid body sets    :  392
number of nodes        :  36323
number of elements     :  31350
    solid elements     :  7842
    beam  elements     :  202
    shell elements     :  23306
  t-shell elements     :  0
nodal results          :
    displacements      : yes
    velocities         : yes
    accelerations      : yes
    temperature        : no
element results        :
  variables per solid  :  7
  variables per beam   :  6
  variables per shell  :  33
  variables per t-shell:  21
# int.-pnts per beam   :  0
# int.-pnts per shell  :  3
# int.-pnts in plane   :  1
add. var. for solid-ip :  0
add. var. for shell-ip :  0
stress tensor  (shells): yes
plastic strain (shells): yes
all resultants (shells): yes
thick + energy (shells): yes
strain tensor  (shells): no
strain tensor  (solids): no
global variables       :  5363
number of stonewalls   :  4
```

Tools to create, visualize and modify interface files

- **seghandle** visualization and modification of interface files (`infmak`)
- **plot2bc2** reads `d3plot` and writes LS-DYNA input files with boundary conditions cards or interface data (`infmak`)

Tools for evaluation of simulation data

- **plot2nodout** create `nodout` from `d3plot`
- **plotintrusion** max intrusion from `d3plot`
- **nodrel3** convert `nodout` and `secforc` to different reference coordinate system
- **rcrel** convert `rcforc` to different reference coordinate system

plotintrusion -h

```
usage: plotintrusion [options]

options:
-x|y|z          direction for intrusion to check
                  (default:  x )
-dir dir-file   file with x-y-z values for intrusion vector
                  (default:  1 0 0 )
-ndir 2n-file   file with 2 nodes defining intrusion vector
                  (direction is from n1 to n2)
-rev            reverse direction defined above
-------------------------------------------------------------
-rel ref-file   file with three nodes that define fixed system
                  (default:  global system)
-------------------------------------------------------------
-g plotfile     LS-DYNA binary plot geometry data file
                  (default: d3plot)
-------------------------------------------------------------
-m part-file    file name for list of parts to be in/excluded
                  (default: all parts are included)
                  syntax of part-file:
                  -id        excludes part with id
                   id        includes part with id
                   id1-id2   includes parts from id1-id2
-excl           parts in part-file are excluded (option -m)
                  (default: parts are included)
-box boxfile    file name for min/max coordinate range (box)
                  (default: all elements are included)
                  syntax of box-file:
                  xmin=value, ... , zmax=value
                  (format and order are arbitrary)
-nofail         consider only nodes of active elements
                  (check failed element info on last state)
-------------------------------------------------------------
-opt opt-file   give options & values above in one file
                syntax of opt-file: eg
                -dir  x y z          (direction)
                -ndir n1 n2          (nodal direction)
                -rel  n1 n2 n3 (nodal fixed system)
                -g  plotfile     (binary d3plotfile)
                -m  mat-range      (part definition)
                    mat-range      (part definition)
                       ...         (part definition)
                -box box-range (min/max definition)
-------------------------------------------------------------
-list           list content of plotfile
-v              gives version number and author
-h              give this help on screen
```

Beispiel: plotintrusion -opt *optfile*

```
title of plotfile      : Tutorial 5 Front crash
 total number of intrusion nodes: 397
 output in ref.system defined by nodes:
     42271     42011     42544
 local x,y,z  =  global x,y,z  at time 0.0000
 intrusion is measured in -1.000 0.000 0.000-direction
   time:      act. intrusion   at node | max. intrusion   at node
 0.000000E+00       0.00000     39000 |        0.00000     39000
 4.999050E+00       0.11121     39239 |        0.11121     39239
 9.999450E+00       0.27655     39239 |        0.27655     39239
 1.499985E+01       0.74072     39264 |        0.74072     39264
 1.999890E+01       3.93195     39157 |        3.93195     39157
 2.499930E+01       7.47845     39160 |        7.47845     39160
 2.999970E+01      12.60858     39160 |       12.60858     39160
 3.499875E+01      17.87921     39160 |       17.87921     39160
 3.999915E+01      25.75696     39160 |       25.75696     39160
 4.499955E+01      37.78589     39157 |       37.78589     39157
 4.999995E+01      50.40070     39157 |       50.40070     39157
 5.499900E+01      60.83337     39203 |       60.83337     39203
 5.999940E+01      70.05701     39244 |       70.05701     39244
 6.499979E+01      81.74316     39244 |       81.74316     39244
 6.999885E+01      86.99683     39150 |       86.99683     39150
 7.499924E+01      90.51056     39244 |       90.51056     39244
 7.999964E+01      90.90021     39244 |       90.90021     39244
 8.499870E+01      86.96240     39244 |       90.90021     39244
 8.999909E+01      79.99823     39244 |       90.90021     39244
 9.499950E+01      73.80933     39244 |       90.90021     39244
 9.999989E+01      68.97272     39244 |       90.90021     39244
 1.049989E+02      65.56384     39244 |       90.90021     39244
 ...
 1.299996E+02      68.50287     39244 |       90.90021     39244
 1.350000E+02      69.38519     39244 |       90.90021     39244
 1.399990E+02      69.35944     39244 |       90.90021     39244
 1.449994E+02      69.63617     39244 |       90.90021     39244
 1.499998E+02      70.05444     39244 |       90.90021     39244
 1.500012E+02      70.05444     39244 |       90.90021     39244
```

optfile:

```
-rev
-m 36
-rel 42271 42011 42544
```

Tools to get informations from LS-DYNA output

- **check-hsp** summarize model information from `d3hsp`
- **check13/check-c** information about contact type of the model and initial penetrations in `messag`
- **check-failed** check for failed elements and nodes with NaN in `messag`

Beispiel: check-c messag000*

```
================================
Interface ID:       1        max:
penetrations:      15     4.47675
    mid-face:      80     4.82246
================================
Interface ID:   82001        max:
 separations:      64     0.34573
================================
```

Beispiel: check-c -list -rsort messag000*

```
================================
Interface ID:       1        max:
penetrations:      15     4.47675
      node       penetration   remaining
---------------------------------------
     11002        0.77796105  0.38452500
     83014        0.36075668  0.39322800
     84018        0.35766088  0.39638200
     32032        0.44816196  0.44184600
     48185        0.21772868  0.54951600
     48618        0.16992025  0.58409500
     47618        0.16949107  0.58452400
    205054        0.80829741  0.73564500
...

mid-face:      80     4.82246
mid-face node    penetration
----------------------------
    136079        4.82246400
    136158        4.82228800
    136150        4.52291100
    136071        4.52282400
    162042        2.07558100
    162026        2.07452500
     60092        1.97280900
...
```

```
================================
Interface ID:   82001        max:
 separations:      64     0.34573
      node         separation
----------------------------
   8200090        0.34573087
   8200108        0.34573085
   8200111        0.34573085
   8200099        0.34573085
   8202464        0.34571493
   8202446        0.34571493
   8200087        0.34570857
   8200078        0.34570848
   8202467        0.34569256
   8200102        0.34568863
...
```

Beispiel: check-c -list -psum messag000*

ptyp:	pid:	summ:	0.0-0.1:	0.1-0.2:	0.2-0.3:	0.3-0.4:	0.4-...:	max:
shell	23	8	0	0	0	0	8	1.74500
shell	46	7	0	1	0	0	6	1.82483
shell	146	6	1	0	0	0	5	0.76653
shell	135	5	0	0	0	0	5	4.82246
shell	25	4	0	0	0	0	4	1.74500
shell	11	4	0	0	0	0	4	1.13787
shell	42	4	0	0	0	0	4	1.10900
shell	145	4	1	0	0	0	3	0.76736
shell	47	4	0	1	1	0	2	0.72381
shell	195	3	0	0	0	0	3	2.07558
shell	10	3	1	0	0	0	2	1.09300
solid	191	3	0	0	0	0	3	0.93281
shell	199	3	0	0	0	0	3	0.93281
shell	132	3	0	0	0	0	3	0.71337
shell	131	3	0	0	0	0	3	0.70976
shell	156	2	0	0	0	0	2	0.67019
shell	69	1	0	0	0	0	1	1.19866
shell	4	1	0	0	0	0	1	0.99264
shell	35	1	0	0	0	0	1	0.86863
shell	122	1	0	0	0	0	1	0.85355
shell	164	1	0	0	0	0	1	0.80830
shell	147	1	0	0	0	0	1	0.77307
shell	6	1	0	0	0	0	1	0.73573
shell	98	1	0	0	0	0	1	0.68596
shell	40	1	0	0	0	0	1	0.64666
shell	94	1	0	0	0	0	1	0.64466
shell	157	1	0	0	0	0	1	0.62620
shell	30	1	0	0	0	0	1	0.44816
shell	81	1	0	0	0	1	0	0.36076
shell	82	1	0	0	0	1	0	0.35766

Beispiel: check-failed -list -pid messag000*

```
PID      51  beam #  1918368 failed at time 0.00707949
PID      51  beam #  1918365 failed at time 0.00708246
PID      51  beam #  1918369 failed at time 0.00718047
PID      56 shell #  2050899 failed at time 0.0103841
PID      56 shell #  2050900 failed at time 0.0103841
PID      56 shell #  2045639 failed at time 0.0158994
PID      56 shell #  2045640 failed at time 0.0159073
PID      63  beam #  1075800 failed at time 0.0160073
PID      56 shell #  2055341 failed at time 0.016037
PID      56 shell #  2055342 failed at time 0.0160845
PID      57 solid #  2783471 failed at time 0.0162212
PID      57 solid #  2783472 failed at time 0.016235
...
PID      57 solid #  2779659 failed at time 0.0934283
PID      56 shell #  2051335 failed at time 0.0959567
PID      57 solid #  2780323 failed at time 0.096031
PID      56 shell #  2051336 failed at time 0.0960577
PID      56 shell #  2051410 failed at time 0.0960953
PID      56 shell #  2051337 failed at time 0.0962141
PID 5000066 solid #  5000839 failed at time 97732      (negative volume)

Part summary:
 beam-PID      51,      4 failed
shell-PID      56,    383 failed
solid-PID      57,   1778 failed
 beam-PID      63,      2 failed
solid-PID 5000066,      1 failed,    1 negative volume

Summary:
shell elements:    383 failed,       0 negative Jacobian
beam  elements:      6 failed,       0 attached shell failed
solid elements:   1779 failed,       1 negative volume
```

The End

Thank you for your attention!