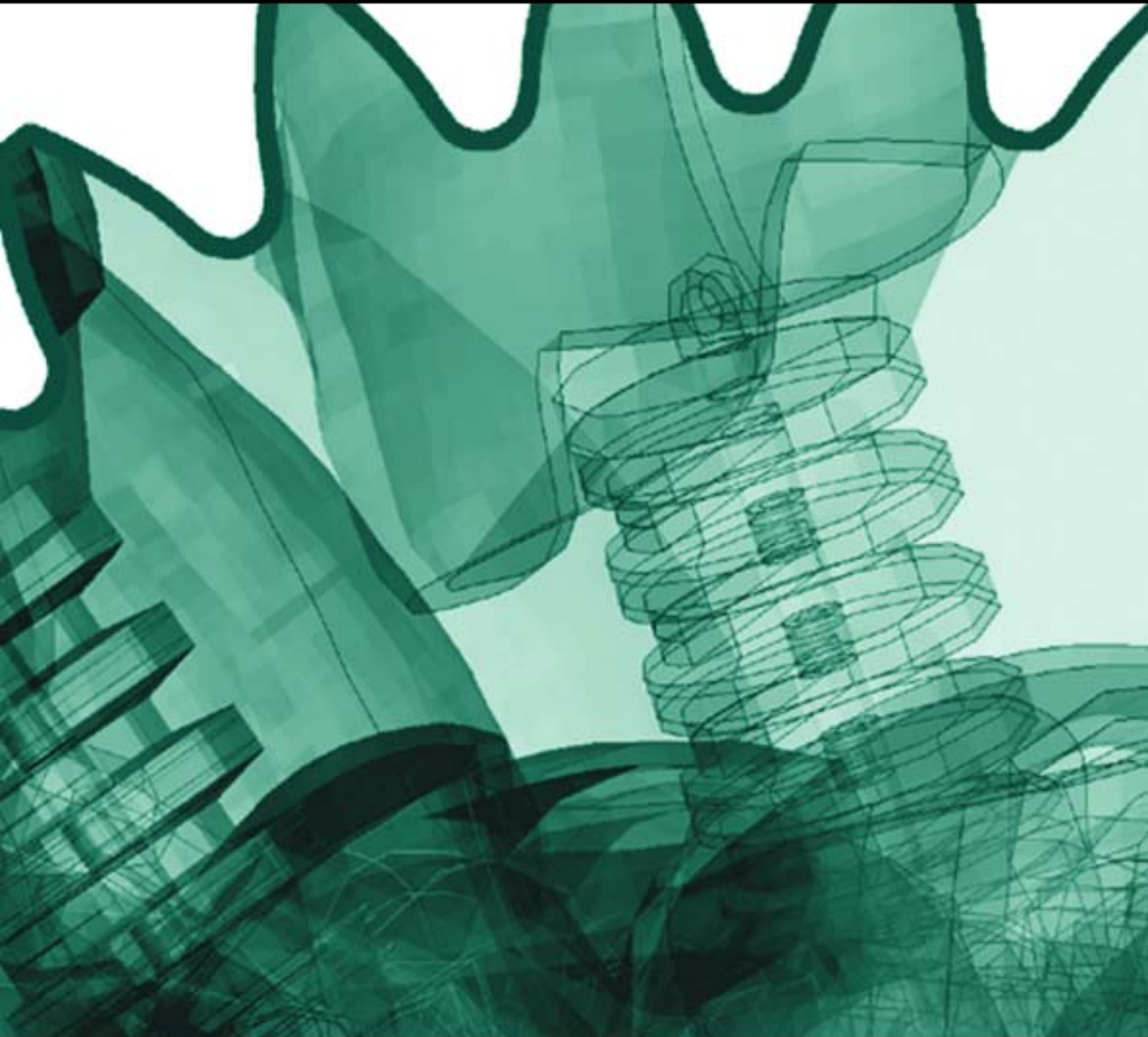


# LS-DYNA Software

Version 971 (R2) builds 7600.1116 & 7600.1224  
Release Notes



ARUP

*Oasys*

The software house of Arup

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# 1. INTRODUCTION

LS-DYNA 971 build 7600 is a major release of the LS-DYNA software. This is also known as LS-DYNA 971 Release 2.

There are two revisions of this build; 7600.1116 and 7600.1224. The 7600.1224 revision is a minor bug-fix version over 7600.1116.

This release is not being issued to clients on CD. The software can be downloaded from the Oasys Ltd website at: [www.arup.com/dyna](http://www.arup.com/dyna).

The version, revision (build) number and date of the LS-DYNA code are as follows:

Version 971 R2  
Revision 7600.1116 and 7600.1224

The revision number, precision and version type can be checked in the test box printed at the top of the .OTF and MESSAG files as per the example below.

```

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-----
LS-DYNA, A Program for Nonlinear Dynamic
Analysis of Structures in Three Dimensions
Version : ls971s R2           Date: 06/12/2007
Revision: 7600.1116        Time: 21:31:24
- version
- revision (build) number

Features enabled in this version:
  Shared Memory Parallel
  ANSYS Database format
  ANSYS License (ans110)
- SMP / MPP

Licensed to: ATG OVE ARUP
Issued by : arup

Platform : PC WIN32
OS Level : Windows XP Pro SP2 B2600
Compiler : Intel Fortran Compiler 9.1
Hostname  : MCCPC063220
Precision : Single precision (I4R4)
- precision

Unauthorized use infringes LSTC copyrights
    
```

Not all variants are available on all platforms and operating systems. The table below gives the variants that are available at present:

Machine	OS	SMP		MPP	
		Precision		Precision	
		Single	Double	Single	Double
HP-PARISC	UX 11	✓	✓	✓	✓
HP-IA64	UX 11	✓	✓	✓	✓
Linux – IA32*		✓	✓	✓	✓
Linux – IA64*		✓	✓	✓	✓
Linux – EM64T*		✓	✓	✓	✓
Linux – AMD*		✓	✓	✓	✓
IBM	AIX 5.1	✓	✓	✓	✓
IBM	AIX 5.3	✓	✓	✓	✓

---

SGI	Irix 6.5	✓	✓	✓	✓
SUN	Solaris 5.6-5.8	✓	✓	✓	✓
Windows – Win32	XP	✓	✓	✓	✓
Windows – Win64	XP	✓	✓	✓	✓

\* Note: There are several executables for different combinations of kernel build and MPI libraries – see Installation Guide for details.

## 2. ENHANCEMENTS AND MODIFICATIONS MADE TO VERSION 971 R2 UP TO BUILD 7600.1116

**Please note; some of the new features, listed below, were also added to later releases of version 970.**

**Also; some definitions have been included in multiple sections for convenience.**

### 2.1 ADAPTIVITY

- H-adaptive fusion is now possible as an option with the control input, \*CONTROL\_ADAPTIVE.
- Added a parameter on, \*CONTROL\_ADAPTIVE, to specify the number of elements generated around a 90 degree radius. A new option to better calculate the curvature was also implemented.
- Added a new keyword: \*CONTROL\_ADAPTIVE\_CURVE, to refine the element along trimming curves.
- Added \*DEFINE\_SET\_ADAPTIVE to allow the adaptive level and element size to be specified by part ID or element set ID.
- Added error checking for improper nodal constraints on r-adaptive nodes in solid elements.
- Fixed bug in 3d-adaptivity if not all parts are adapted.
- Some improvements to \*CONTROL\_ADAPTIVE\_CURVE.
- Fix bug in 2d r-adaptive where \*LOAD\_SEGMENT is treated as in 3d adaptivity.
- Fixed bug in adaptivity triggered if any element fails.
- Fixed problems related to MPP and adaptivity.

### 2.2 AIRBAGS

- A simplified method for using the ALE capability with airbags is now available with the keyword \*AIRBAG\_ALE.
- Airbag simulations by using ALE method can be switched to control volume method by \*ALE\_CV\_SWITCH.
- Enabled users to input AIR and GAS Part ID for \*AIRBAG\_ALE and \*AIRBAG\_ADVANCED\_ALE

### 2.3 ALE

- A simplified method for using the ALE capability with airbags is now available with the keyword \*AIRBAG\_ALE.
- New binary database FSIFOR for fluid structure coupling.
- Airbag simulations by using ALE method can be switched to control volume method by \*ALE\_CV\_SWITCH.
- \*MAT\_ALE\_VISCOUS now supports Non-Newtonian viscosity by power law or load curve.

- \*DATABASE\_BINARY\_FSIFOR outputs fluid-structure interaction data to binary file.
- \*DATABASE\_FSI\_SENSOR outputs ALE element pressure to ASCII file dbdor.
- \*MAT\_GAS\_MIXTURE supports nonlinear heat capacities.
- \*INITIAL\_VOLUME\_FRACTION\_GEOMETRY uses an enhanced algorithm to handle both concave and convex geometries and substantially reduce run time.
- A new keyword \*DELETE\_FSI allows the deletion of coupling definitions.
- Convection heat transfer activates by \*LOAD\_ALE\_CONVECTION in ALE FSI analysis.
- \*ALE\_FSI\_SWITCH\_MMG is implemented to switch between ALE multi-material groups to treat immersed FSI problems.
- New options in \*CONSTRAINED\_LAGRANGE\_IN\_SOLID:
  - Shell thickness option for coupling type 4.
  - Bulk modulus based coupling stiffness.
  - Shell erosion treatment.
  - Enable/disable interface force file.
- Type 9 option is added in \*ALE\_REFERENCE\_SYSTEM\_GROUP to deal complex ALE mesh motions including translation, rotation, expansion and contraction, etc.
- New coupling method for fluid flowing through porous media are implemented as type 11 (shell) and type 12 (solid) in \*CONSTRAINED\_LAGRANGE\_IN\_SOLID.
- Enabled users to input AIR and GAS Part ID for \*AIRBAG\_ALE and \*AIRBAG\_ADVANCED\_ALE
- Added new MPP decomposition option, aledist, to allow user to distribute internally generated ALE elements to all processors (MPP only).
- Bug fix for a coupled thermal-mechanical problem using the ALE element formulation 12 (single material and void).
- Bug fix for ale rezoning for equipotential and isoparametric options.
- Enhance volume fraction filling algorithm to take care of very large dimensional model
- Relax upper bound of leakage control starting volume fraction to 0.6 to avoid instability when both sides of the structure have leakage control

## 2.4 BEAM ELEMENTS

- Section properties can be defined in the \*ELEMENT\_BEAM definitions for resultant beam elements using the SECTION option.
- Twenty-two built-in cross-sections are now available in the definition of beam integration rules, see \*INTEGRATION\_BEAM.
- Damping defined in \*DAMPING\_PART\_STIFFNESS now works for the Belytschko Schwer beam element.
- The Hughes-Liu beam has been extended to include warpage for open cross-sections.
- A resultant beam formulation with warpage is available as beam type 12.

- Fix bug related to mass scaling and constrained beam offset option.
- Bug fix for \*ELEMENT\_BEAM option where n2=-n1 grounds the discrete beam.

## 2.5 CONSTRAINTS & SPOTWELDS

- Butt weld definition by using the \*CONSTRAINED\_BUTT\_WELD option which makes the definition of butt welds simple relative to the option:  
\*CONSTRAINED\_GENERALIZED\_WELD\_BUTT.
- Added an option to scale the spot weld failure resultants to account for the location of the weld on the segment surface, see  
\*CONTROL\_SPOTWELD\_BEAM.
- Added an option automatically replace a single beam spot weld by an assembly of solid elements using the same ID as the beam that was replaced, see  
\*CONTROL\_SPOTWELD\_BEAM.
- Boundary constraint in a local coordinate system using  
\*CONSTRAINED\_LOCAL keyword.
- A cubic spline interpolation element is now available, \*CONSTRAINED\_SPLINE.
- SPOTHIN option on the \*CONTROL\_CONTACT keyword cards locally thins the spot welded parts to prevent premature breakage of the weld by the contact treatments.
- A new keyword, \*DEFINE\_HEX\_SPOTWELD\_ASSEMBLY, is available to define a cluster of solid elements that comprise a single spotweld.
- The definition of a failure criteria between part pairs is possible with a table defined using the keyword, \*DEFINE\_SPOTWELD\_FAILURE\_RESULTANTS.
- A new keyword, \*DEFINE\_CONNECTION\_PROPERTIES is available for defining failure properties of spot welds.
- Static rupture stresses for beam type spot welds can be defined in the keyword input, \*DEFINE\_SPOTWELD\_RUPTURE\_STRESS.
- New options for spotweld failure in \*MAT\_SPOTWELD, which apply to beam and solid elements.
- New options in \*CONSTRAINED\_LAGRANGE\_IN\_SOLID:
  - Shell thickness option for coupling type 4.
  - Bulk modulus based coupling stiffness.
  - Shell erosion treatment.
  - Enable/disable interface force file.
- New coupling method for fluid flowing through porous media are implemented as type 11 (shell) and type 12 (solid) in \*CONSTRAINED\_LAGRANGE\_IN\_SOLID.
- Set number of failures till rupture to 1 if input as zero for beam failure type so that the welds do not fail immediately.
- Improved error reporting when problems arise with the use of  
\*CONSTRAINED\_LINEAR, \*CONSTRAINED\_INTERPOLATION, or  
\*CONTROL\_IMPLICIT\_INERTIA\_RELIEF in an implicit analysis.
- Enabled the used of \*CONSTRAINED\_SPOTWELD massless spot welds with implicit analysis.

- Enabled nodal rigid bodies to be connected by Joints.
- Fixed spot welds such that the time step size does not become too small after a automatically switching from implicit to explicit analysis.
- Fixed 2-sheet type 9 beam spotweld failure with the rate sensitive parameter option
- Fix Toyota's new 3 sheet weld failure criteria as well as it's extension to the 2 sheet case.
- Fix for zero divide for spotweld failure option type 1.
- Added load curves to account for rate effects in  
\*DEFINE\_SPOTWELD\_RUPTURE\_PARAMETERS
- Fixed linear curve interpolation routine for type 9 beam spotweld failure to stop extrapolation of dynamic scale factor curves.
- Corrected shear load rate calculation for type 9 beam spotweld failure with dynamic load scale factor curves. Before the fix, the rate was much too large.
- Fix for resetting mass of spotweld beam element which is lengthened for tied contact.
- Fix for spotweld beam to prevent huge energy excursions.
- Delete solid spotwelds if surrounding shells fail and update \*CONTACT\_SPOTWELD accordingly.
- Added spotweld neighbour segment thinning.
- Fixed some problems with define connection spotweld failure. Now, the check for improper tied contact type works.
- Fix for \*BOUNDARY\_PRESCRIBED\_MOTION for the acceleration of node of a nodal rigid body.
- Fix problem with \*CONSTRAINED\_NODAL\_RIGID\_BODY\_INERTIA. If any of the nodal rigid bodies preceding this in the input get merged out due to common nodes, the inertia would be applied to the wrong nodal rigid body, in some cases overwriting memory with unpredictable results.
- Fix bug related to \*CONSTRAINED\_NODAL\_RIGID\_BODY\_SPC and also updated formats.
- Fixed an error for \*CONSTRAINED\_NODAL\_RIGID\_BODY if RRFLAG is negative.
- Fixed bug related to deleted nodal rigid bodies which caused energy growth.
- Minor fix for constraints on rigid bodies related to round-off.
- Fixed beam spotwelds with OPT=9 failure which were broken when rate effects were added (MPP only).
- Zeroed the body force on the dependent nodes of rbe3 constraints.
- Modified beam spot weld type 9 failure. Now, the moment used in the failure calculation will be assumed to be zero if the axial weld stress is compressive.
- Fixed the rate affects in type 9 beam spot weld failure.
- Fixed possible divide by zero error in beam spot weld failure type 5.
- Fixed mass scaling message for spot welds.

## 2.6 CONTACT

- New option to forming contact:  
\*CONTACT\_FORMING\_ONE\_WAY\_SURFACE\_TO\_SURFACE\_SMOOTH,  
which use fitted surface in contact calculation.
- SPOTHIN option on the \*CONTROL\_CONTACT keyword cards locally thins the spot welded parts to prevent premature breakage of the weld by the contact treatments.
- Added new contact type \*CONTACT\_GUIDED\_CABLE.
- Friction can now be defined between part pair using the \*DEFINE\_FRICTION input.
- Fixed segment based contact to eliminate a discontinuity in the friction force when the normal force dropped to zero related to a switch for surface to edge-to-edge contact or vice versa.
- Fixed full deck restarts with SMP segment based contact. Before, the fix, spikes in contact force were possible after the restart in an area that had large initial penetration before the restart.
- Added support for thermal contact birth/death time.
- Fixed MPP segment based eroding contact. Before the fix, interior solid element segments (those not on the surface of a part) would be checked for contact if these segments were on the MPP decomposition boundary. These segments could prevent smooth sliding of one part along another but otherwise probably didn't cause too much trouble.
- Modified MPP INTERFERENCE contact to not honour "IGNORE" flag until stiffness has been fully scaled up to 1.0. Before the change, if the ignore flag was on, the interfering nodes were generating no forces due to the penetration compensation.
- Fixed problem with dynamic relaxation and contact entities.
- Added support for \*DEFINE\_CONTACT\_VOLUME for SPH elements, which was not working.
- Fixed a segment based contact problem when used with 2-surface force transducers that could cause an infinite loop when one segment has nodes on both surfaces.
- Fix bug in beam contact when there is only one beam.
- Bug fix related to tied contacts where the master and slave thickness are specified as negative values.
- Fixed SMP thread problems in 2D automatic contact that could cause unpredictable results.
- Added square shell edge option to segment base contact  
Activate by setting SHLEDG=1 on \*CONTROL\_CONTACT  
SHLEDG is the first parameter on the new 6th card
- Fixed a problem with segment based eroding surface to surface contact that could cause penetration of solid parts after erosion.
- Fixed 2-surface force transducer contact when used with segment based contact.
- Fix for initialization problem of CONTACT\_GUIDED\_BEAM: incorrect neighbours were being computed on one end of each beam, resulting in errors as the beams moved along the guide nodes (SMP and MPP)

- Fix for round-off problem related to contact boxes.
- Fix to automatic\_tiebreak contact due to differences between 970 and 971.
- Fixed some problems with define connection spotweld failure. Now, the check for improper tied contact type works.
- Added failure messages if a node is released for automatic\_tiebreak OPTION=5,6,7.
- Fix problem with MPP guided cable contact in case the number of nodes or beams is different between different interfaces.
- Fixes to \*CONTACT\_FORCE\_TRANSDUCER for slave-master definition.
- Fix for seatbelt slip-ring node in contact.
- Fixed energy calculation in symmetric treatment of segment-based contact in case where segments in contact have nearly colinear normals.
- Fixes for OFFSET tied contacts which fail to release when attached segment is deleted.
- Fix for surface to surface tied interfaces to release constraint if segment fails.
- Fixed bug affecting contact forces for contact entities (MPP only).
- Fixed memory allocation problem in MPP related to tied contact initialization.
- Add MPP constrained contact check: if a slave or master node is in more than one constrained interface, issue a warning and release the node. This check was already in SMP.
- Fix for MPP 2-surface force transducers when used with segment-based contact for the case when some processors in the contact communicator do not have any force transducer contacts defined.
- Fixed error in MPP segment-based contact when there are control volumes in the data.
- Fix user defined thickness in tied contact (MPP only).
- Fix possible case of MPP eroding contact failure: if segment list was used for one of the side definitions, some contact segments might get lost.
- Change to MPP contact release condition to better handle the case where both the slave and master sides have zero thickness.
- Fix for MPP TIEBREAK contact initialization, in case a slave node is near two separate slave segments, it was sometimes not taking the closest one.
- Add additional check which SMP code does to avoid tie to the wrong segment resulting in a short beam controlling the time step (MPP only).
- Fixed MPP bug related to initialization of tied interfaces: ALL interfaces were being treated as constrained when checking for nodes involved in more than one tied interface, causing some nodes to be incorrectly deleted from penalty based tied interfaces.

## 2.7 DATABASE & OUTPUT

- Circular cut planes are available for \*DATABASE\_CROSS\_SECTION definitions.
- New binary database FSIFOR for fluid structure coupling.
- Added \*DATABASE\_BINARY\_D3PROP for writing the material and property data to the first D3PLOT file or to a new database D3PROP.

- DATABASE\_EXTENT\_BINARY has new flags to output peak pressure, surface energy density, nodal mass increase from mass scaling, thermal fluxes, and temperatures at the outer surfaces of the thermal shell.
- Two NODOUT files are now written: one for high frequency output and a second for low frequency output.
- Nodal mass scaling information can now be optionally written to the D3PLOT file.
- Added option, MASS\_PROPERTIES, to include the mass and inertial properties in the GLSTAT and SSSTAT files.
- Added option in \*CONTROL\_CPU to output the cpu and elapsed time into the GLSTAT file.
- Added an option, IERODE, on the \*CONTROL\_OUTPUT keyword to include eroded energies by part ID into the MATSUM file. Lumped mass kinetic energy is also in the MATSUM file as part ID 0.
- Added an option, TET10, on the \*CONTROL\_OUTPUT keyword to output ten connectivity nodes into D3PLOT database rather than 4.
- The interface springback file created by using the keyword, \*INTERFACE\_SPRINGBACK is now optionally written as a binary file.
- \*DATABASE\_BINARY\_FSIFOR outputs fluid-structure interaction data to binary file.
- \*DATABASE\_FSI\_SENSOR outputs ALE element pressure to ASCII file dbSor.
- Added option for MSC/DBALL database in \*DATABASE\_FORMAT
 

```

*DATABASE_FORMAT
$ iform      ibinary
  iform = 3  msc/dball output only
  iform = 4  msc/dball and d3plot output
      
```
- Fixed option to time average accelerations in nodout and d3thdt files for rigid body nodes (IACOP=1 on \*CONTROL\_OUTPUT)
- Fixed d3thdt output with DCOMP=2 on \*DATABASE\_EXTENT\_BINARY.
- Enabled 32 bit d3thdt and INFMMAK files to be written on 64 bit systems.
- Added option to print digitized curve data to d3hsp & d3msg using the following keyword format:
 

```

$=====
*CONTROL_OUTPUT
$ card 1
...
# card 2
$#1    #2    #3    #4    #5
                                ipcurv
$=====
where ipcurve-flag for printing of digitized curve data to d3hsp
& d3msg
    0-no print
    1-print
      
```
- Fixed bug in writing intfor database if the total number of words exceeded 2G.

- Zero out kinetic energy and momentum for each material for the case of implicit statics.
- Modify pressure output to dbfsi based on segment orientation
- Fix for rigid body velocity calculation in MATSUM where deformable body nodes are shared by rigid body.
- Fix matsum problem with discrete spring elements related to bug report.
- Fixed the output of timestep control if no element controlled the timestep.
- If the timestep is controlled by dt2ms of \*CONTROL\_TIMESTEP, report it as "dt2ms".
- Removed d3thdt at the termination time since the acceleration is incorrect.
- Outputted stress Syz= and Szx=0 to d3plot for materials 36, 37, 122 and 125 if shell formulation is not 24, 25 or 26.
- Fixed bug in the momentum and rigid body velocity output for MATSUM.
- Output number of nodes and elements to glstat if adaptivity is invoked.
- Fixed element numbers in d3part database.
- Updates to thermal and thick shell output.
- Added mass centre co-ordinates to the SSSTAT\_MASS\_PROPERTIES output.
- Added compiler information to banner.
- Fix for SMP output of rforc to binout/lsta in case there are TRANSDUCER type contacts.
- Fixed bug in \*DATABASE\_FSI\_SENSOR.
- Changed pressure output to dbfsi when \*AIRBAG\_ALE(\_ADVANCED) is used output pressure = coupling pressure + ambient pressure.
- Fix inconsistency of rigid body output to d3hsp.
- Fixed bug in \*DATABASE\_SPH if \*DATABASE\_HISTORY\_NODE is not defined.
- Fix for energy calculation bug in material 123.
- Output effective strain for material 187 since effective plastic strain is not available and added internal energy calculation.
- Moved strain rate history information to the first history variable slot for the solid material 24, VP=1 (now consistent for shells and solids).
- Fixed bugs related to acceleration filtering via IACCOP=2 in \*CONTROL\_OUTPUT.
- Saved interface force file name for restart.
- Add echo of decomposition information to the d3hsp and mes0000 files for MPP.
- MPP fixes for interface force file in case there are tied interfaces.
- Modify sensor handling for MPP, to fix problem with PART\_SENSOR.
- Bug fix for ALE dbdsensor (MPP only).
- Made sense switch not case sensitive in d3kil file.
- Fixed dbout output of jntforc converting data from global to the local coordinate system.

- Fixed d3hsp output format for belt materials and belt slip rings so they work for large numbers.

## 2.8 EFG & SPH

- EFG shell formulations 41 and 42 are implemented for explicit analysis.
- EFGPACK is implemented in addition to BCSLIB-EXT solver on the keyword \*CONTROL\_EFG.
- EFG MPP version is available for explicit analysis.
- EFG fast transformation method is implemented in the EFG solid formulation.
- EFG Semi-Lagrangian kernel and Eulerian kernel options are added for the foam materials.
- EFG 3D adaptivity is implemented for the metal materials.
- EFG E.O.S. and \*MAT\_ELASTIC\_FLUID materials are included in the 4-noded background element formulation.
- Added secforc calculations for EFG solids and EFG shells.
- Fixed sorting of EFG shell 41 for 3-node/4-node background element.

## 2.9 FORMING

- New function: \*CONTROL\_FORMING\_PROJECT, which can initial move the penetrating slave nodes to the master surface
- New function \*CONTROL\_FORMING\_TEMPLATE, which allows user to easily set-up input deck. Its functions include auto-position, define travel curve, termination time, and most of the forming parameters for most of the typical forming process.
- New function \*CONTROL\_FORMING\_USER, \*CONTROL\_FORMING\_POSITION, and \*CONTROL\_FORMING\_TRAVEL, when used together, can allow user to define a typical forming process.
- Tubular drawbead box option for defining the elements that are included in the drawbead contact, see \*DEFINE\_BOX\_DRAWBEAD.
- New function: \*DEFINE\_CURVE\_DRAWBEAD, allow user to conveniently define drawbead by using curves (in x, y format or iges format).
- New function: \*DEFINE\_DRAWBEAD\_BEAM, which allows user to conveniently define drawbead by using beam part ID, and specify the drawbead force.
- Analytic function can be used in place of load curves with the option \*DEFINE\_CURVE\_FUNCTION.
- New keyword: \*DEFINE\_CURVE\_TRIM\_3D, to allow trimming happens based on blank element normal, rather than use pre-defined direction.
- A new trimming algorithm was added: \*DEFINE\_CURVE\_TRIM\_NEW, which allow seed node to be input and is much faster then the original algorithm.
- New features to \*INCLUDE\_STAMPED\_PART: two different mirror options, user-defined searching radius.

- The interface springback file created by using the keyword, \*INTERFACE\_SPRINGBACK is now optionally written as a binary file.
- Modified MPP drawbead contact to better match SMP.

## 2.10 IMPLICIT

- Birth and death times for implicit dynamics on the keyword \*CONTROL\_IMPLICIT\_DYNAMICS.
- Static implicit analyses in of a structure with rigid body modes is possible using the option, \*CONTROL\_IMPLICIT\_INERTIA\_RELIEF.
- Superelements can now share degrees-of-freedom and are implemented for implicit applications under MPI.
- Enabled discrete beam material 74 to be used for implicit analysis.
- Fixed the shell element drilling d.o.f. force calculation for multiple processor SMP implicit.
- Enabled implicit hyperelastic hourglass control (type 7) in solid elements.
- Fixed non-zero birth times for implicit dynamic analysis, TDYBIR>0 on \*CONTROL\_IMPLICIT\_DYNAMICS.
- Improved treatment of rigid body spc's in local coordinates in implicit solutions.
- Fixed spot welds such that the time step size does not become too small after a automatically switching from implicit to explicit analysis.
- Enabled the use of joints for implicit analysis in the MPP code.
- Add thick shell types 1 and 2 for linear implicit analysis.
- Fixed a memory error with material type 3 in implicit analysis.

## 2.11 INPUT

- Eight-character alphanumeric labels can now be used for the parameters SECID, MID, EOSID, HGID, and TMID on the \*PART keyword.
- New keyword, \*ELEMENT\_MASS\_PART defines the total additional non-structural mass to be distributed by an area weighted distribution to all nodes of a given part ID.
- New option allows the number of cpu's to be specified on the \*KEYWORD input.x
- The definition of a vector, see \*DEFINE\_VECTOR, can be done by defining coordinates in a local coordinate system.
- File names can be located in remote directories and accessed through the \*INCLUDE\_PATH keyword.
- New features to \*INCLUDE\_STAMPED\_PART: two different mirror options, user-defined searching radius.
- \*INITIAL\_STRESS\_SECTION allows for stress initialization across a cross-section, which consists of solid elements.
- An option, IVATN, is available for setting the velocities of slaved nodes and parts for keyword, \*INITIAL\_VELOCITY\_GENERATION.

- Twenty-two built-in cross-sections are now available in the definition of beam integration rules, see \*INTEGRATION\_BEAM.
- An optional input line for \*KEYWORD allows the definition of a prefix for all file names created during a simulation. This allows multiple jobs to be executed in the same directory.
- Thermal expansion can be added to any material by the keyword, \*MAT\_ADD\_THERMAL\_EXPANSION.
- There is now an interface with the MOLDFLOW code.
- The option \*NODE\_TRANSFORMATION allows a node set to be transformed based on a transformation defined in \*DEFINE\_TRANSFORMATION.
- Parameters can be defined in Fortran like expressions using \*PARAMETER\_EXPRESSION.
- A part can be moved in a local coordinate system in \*PART\_MOVE.
- A simplified method for defining composite layups is available with \*PART\_COMPOSITE
- A part set can now be defined by combining other part sets in \*SET\_PART\_ADD.
- Termination of the calculation is now possible if a specified number of shell elements are deleted in a give part ID. See \*TERMINATION\_DELETED\_SHELLS.
- Increased to 9 the number of digits in part, section, material, eos, hourglass and thermal ID numbers.
- Added the keyword \*SET\_2D\_SEGMENT to define line segments for 2D analyses.
- Fixed bug in reading stress initialization file (m=file) if jobid option is used.
- Fixed \*INCLUDE\_TRANSFORM bugs, including those related to:
  - \*CONSTRAINED\_JOINT\_STIFFNESS
  - \*MAT\_020 (rigid)
  - \*MAT\_196 (discrete beam)
  - \*DEFINE\_COORDINATE\_VECTOR
  - \*CASE
- Fixed \*PARAMETER if "&" is not at the first column.
- Bug fix for \*SET\_PART\_ADD with set offsets defined.
- Fix potential bug for \*CONTROL\_CHECK\_SHELL when multiple parts are defined.
- Added new parameter ISNAN in \*CONTROL\_SOLUTION
 

```

*CONTROL_SOLUTION
$  solu  nlq  isnan
$   I   I   I
$   0   0   0
ISNAN  Flag to check any NaN in moments/forces after element formulation
      0-no check
      1-check
      The command option "checknan=1" or the sense switch control "swn" can activate this
      option as well.
```

- Bug fix for \*CONTROL\_DYNAMIC\_RELAXATION (MPP only).
- Fixed shell element stress mapping by \*INITIAL\_STRESS\_SHELL.
- Fixed stress initialization for tetrahedral elements of element formulation 4.

## 2.12 LOADING

- Body force loads can now be applied in a local coordinate system for \*LOAD\_BODY.
- A pressure loading feature allows moving pressures to be applied to a surface to simulate spraying a surface with stream of fluid through a nozzle. See keyword \*LOAD\_MOVING\_PRESSURE.
- Convection heat transfer activates by \*LOAD\_ALE\_CONVECTION in ALE FSI analysis.

## 2.13 MATERIAL

- Thermal expansion can be added to any material by the keyword, \*MAT\_ADD\_THERMAL\_EXPANSION.
- Curves can now be used instead of eight digitized data points in the material model \*MAT\_ELASTIC\_WITH\_VISCOSITY\_CURVE.
- New options for spotweld failure in \*MAT\_SPOTWELD, which apply to beam and solid elements.
- Failure criteria based on plastic strain to failure is added to material \*MAT\_ANISOTROPIC\_VISCOPLASTIC.
- Strain rate failure criterion is added to material \*MAT\_MODIFIED\_PIECEWISE\_LINEAR\_PLASTICITY.
- Strain rate scaling of the yield stress can now be done differently in tension and compression in material with separate pressure cut-offs in tension and compression in material model \*MAT\_PLASTICITY\_TENSION\_COMPRESSION.
- The RCDC model is now available to predict failure in material \*MAT\_PLASTICITY\_WITH\_DAMAGE.
- Two additional yield surfaces have been added to material \*MAT\_MODIFIED\_HONEYCOMB to provide more accurate predictions of the behaviour of honeycomb barrier models.
- Unique coordinate systems can be assigned to the two nodal points of material \*MAT\_1DOF\_GENERALIZED\_SPRING.
- Poisson's ratio effects are available in foam defined by load curves in the material \*MAT\_SIMPLIFIED\_RUBBER/FOAM
- Failure effects are available in the rubber/foam material defined by load curves in the \*MAT\_SIMPLIFIED\_RUBBER/FOAM\_WITH\_FAILURE.
- The material option \*MAT\_ADD\_EROSION now allows the maximum pressure at failure and the minimum principal strain at failure to be specified.
- Strains rather than displacements can now be used with the material model for discrete beams, \*MAT\_GENERAL\_NONLINEAR\_6DOF\_DISCRETE\_BEAM.

- New option for MAT\_TRANSVERSELY\_ANISOTROPIC\_ELASTIC\_PLASTIC\_(ECHANGE), which allow two ways to change the Young's modulus during forming simulation.
- New Material model: \*MAT\_HILL\_3R: includes the shear term in the yield surface calculation by using Hill's 1948 an-isotropic material model.
- New Material model: \*MAT\_KINEMATIC\_HARDENING\_TRANSVERSELY\_ANISOTROPIC: which integrates Mat #37 with Yoshida's two-surface kinematic hardening model.
- Improved formulation for the fabric material, \*MAT\_FABRIC for formulations 2, 3, and 4. The improved formulations are types 12, 13, and 14.
- Constitutive models added:
  - For truss elements:
    - \*MAT\_MUSCLE
  - For beam elements
    - \*MAT\_MOMENT-CURVATURE
  - For shell elements
    - \*MAT\_RESULTANT\_ANISOTROPIC
    - \*MAT\_RATE\_SENSITIVE\_COMPOSITE\_FABRIC.
    - \*MAT\_SAMP-1
    - \*MAT\_SHAPE\_MEMORY is now implemented for shells.
  - For shell and solid elements:
    - \*MAT\_BARLAT\_YLD2000 for anisotropic aluminium alloys.
    - \*MAT\_SIMPLIFIED\_RUBBER\_WITH\_DAMAGE
    - \*MAT\_VISCOELASTIC\_THERMAL
    - \*MAT\_THERMO\_ELASTO\_VISCOPLASTIC\_CREEP
  - For the solid elements:
    - \*MAT\_ARUP\_ADHESIVE
    - \*MAT\_BRAIN\_LINEAR\_VISCOELASTIC.
    - \*MAT\_CSCM for modelling concrete.
    - \*MAT\_PLASTICITY\_COMPRESSION\_TENSION\_EOS for modelling ice.
    - \*MAT\_COHESIVE\_ELASTIC
    - \*MAT\_COHESIVE\_TH
    - \*MAT\_COHESIVE\_GENERAL
    - \*MAT\_EOS\_GASKET
    - \*MAT\_SIMPLIFIED\_JOHNSON\_COOK is now implemented for solids.
    - \*MAT\_PLASTICITY\_WITH\_DAMAGE is now implemented for solids.
    - \*MAT\_SPOTWELD\_DAIMLERCHRYSLER
- Shell formulations 4, 11, 16, and 17 can now model rubber materials.
- \*MAT\_ALE\_VISCOUS now supports Non-Newtonian viscosity by power law or load curve.
- \*MAT\_GAS\_MIXTURE supports nonlinear heat capacities.
- Fixed a round-off problem for single precision in discrete beam material type 74.
- Fix for material 127 for plane strain 2d elements.

- Fixed types 6, 7, and 9 hourglass control for solid elements with material 4.
- Added error termination if BETA in material 6 is zero.
- Fix for divide by zero during restart with materials 123 and 24 when using the dynain file for initialization.
- Fix for material 76 when bulk viscoelastic constants are specified.
- Corrected material energy in fabric materials 13 and 14 when viscous damping is used.
- Fixes to material 187 related to SMP parallel and also to initialization.
- Fix for material 4 whenever the yield stress is set to zero for the thermoelastic case.
- Fix for material 24, VP=1 with load curve to scale yield stress to account for strain rate effects.
- Fix for material 24, VP=1 for solids that led to a negative internal energy.
- Small modification to fabric material forms 2 and 12 which could generate initial compressive stress when an airbag reference geometry was used and compressive stress elimination is active.
- Fixed rotational instability in material 22 for solid elements.
- Fix for energy calculation bug in material 123.
- Fix for material 72\_R3 to correct potential divide by zero problem on the first cycle.
- Output effective strain for material 187 since effective plastic strain is not available and added internal energy calculation.
- \*MAT\_CONCRETE\_DAMAGE and \*MAT\_CONCRETE\_DAMAGE\_REL3 (materials 72,72r3):
  - Internal energy now calculated and output
  - Works with multi-integration-point element types
- Fixes for material 77 plane stress implementation.
- Fixed solid element hourglass stiffness parameters for material 181 and 183 such that types 6, 7, and 9 hourglass controls should work well for both the compressible and incompressible models.
- Correction in principal stress calculation for material 126 yield surface 2.
- Moved strain rate history information to the first history variable slot for the solid material 24, VP=1 (now consistent for shells and solids).
- Fixed fabric material form 14 to use the unload curve for the b-fiber when defined instead of the load curve. This bug was introduced in R2 revision 789.

## 2.14 MISCELLANEOUS

- Case control using the \*CASE keyword, which provides a way of running multiple load cases sequentially within a single run
- User defined equations-of-state are now available.
- A user defined element interface is available for solid and shell elements.
- Thermal shells are available for treating heat flow through shell elements.

- Added automatic checking of cohesive element orientation to prevent problems with incorrectly numbered elements.
- Fixed SMP parallel consistency option for shell element type 17.
- Enabled super-elements to work for explicit solutions in single precision.
- Fixed rigid walls such that the death time is ignored during dynamic relaxation if the birth time is set to zero.
- Fixed prescribed rigid body accelerations with the scale factor not equal to zero.
- Added options \_3858 and \_5434a to \*DEFINE\_CURVE so that validated models can be run with the same curve discretization.
- Fixed behaviour of rigid walls when the solution changes between implicit and explicit.
- Put in some error checking on super-element problems.
- Fix a problem with super-element input processing.
- Fix initialization of super-elements for the case of implicit/explicit switching.
- Fixed bugs in mapping for \*INCLUDE\_STAMPED\_PART including check of segment normals to get order of integration points right.
- Made various fixes/updates to \*PERTURBATION:
  - More of correct handling of defaults; specified as zero stays zero
  - Fix bug with perturb\_shell\_thickness and adaptivity
  - Fix shell thickness bug using wrong part info
- Extend array dimensions to allow 500 airbags, up from the current 100.
- Added new parameter ISNAN in \*CONTROL\_SOLUTION
 

```

*CONTROL_SOLUTION
$  solu  nlq  isnan
$   I    I    I
$   0    0    0
ISNAN  Flag to check any NaN in moments/forces after element formulation
      0-no check
      1-check
      The command option "checknan=1" or the sense switch control "swn" can activate this
      option as well.
      
```
- Fix bug related to 2D\_Segment sets when multiple sets are defined.
- Fix for 2d thermal adaptive problem with convection boundary conditions (2d segments generated improperly and temperatures for thermal solver were set to the wrong time)
- Extend Hybrid inflator option to work with \_CM jetting.
- Added rigid bodies to 100 step initialization option in \*CONTROL\_DYNAMIC\_RELAXATION
- Fixed bug in \*DEFINE\_COORDINATE\_NODES, FLAG=1 (MPP only).
- Volume calculation of airbag with holes made consistent with SMP.

## 2.15 RESTARTS

- The rigid body inertia can be changed in restart via \*CHANGE\_RIGID\_BODY\_INERTIA.
- A new keyword \*DELETE\_FSI allows the deletion of coupling definitions.
- Fixed full deck restarts with SMP segment based contact. Before, the fix, spikes in contact force were possible after the restart in an area that had large initial penetration before the restart.
- Fixed bug for the restart of adaptivity job if ADPTHK option is used.

## 2.16 SEATBELT ELEMENTS

- Added a new seatbelt pretensioner type 7 in which the pretensioner and retractor forces are calculated independently and added.
- Seatbelt shell elements are available for use with the all seatbelt capabilities.

## 2.17 SHELL ELEMENTS

- Shell element thickness updates can now be limited to part ID's within a specified set ID, see the \*CONTROL\_SHELL keyword. The thickness update for shells can now be optionally limited to the plastic part of the strain tensor for better stability in crash analysis.
- New keyword option, SET, for \*INITIAL\_STRESS\_SHELL\_SET allows a set of shells to be initialized with the state of stress.
- Physical offsets of the shell reference surface can be specified on the shell element cards, see the OFFSET option on \*ELEMENT\_SHELL.
- The possibility of changing material types is now available for shells using the user defined integration rule, see \*INTEGRATION\_SHELL.
- A simplified method for defining composite layups is available with \*PART\_COMPOSITE
- Shell formulations 4, 11, 16, and 17 can now model rubber materials.
- Shell thickness offsets for \*SECTION\_SHELL now works for most shell elements, not just the Hughes-Liu shell.
- Two nonlinear shell elements are available with 8 degrees-of-freedom per node to include thickness stretch.
- Seatbelt shell elements are available for use with the all seatbelt capabilities.
- Added esort=3 option to use DKT triangular shell elements in place of degenerate quad elements.
- Added bulk viscosity to the DKT, type 17, shell element.
- Added bulk viscosity to shell type 4 (C0 triangle).
- Fixed shell element stress mapping by \*INITIAL\_STRESS\_SHELL.

## 2.18 SOLID ELEMENTS

- Solid element stresses in spot welds are optionally output in the local system using the SWLOCL parameter on the \*CONTROL\_SOLID keyword.
- New keyword, \*ELEMENT\_SOLID\_T4TOT10 to convert 4 node tetrahedron elements to 10 node tetrahedron elements.
- A new keyword, \*DEFINE\_HEX\_SPOTWELD\_ASSEMBLY, is available to define a cluster of solid elements that comprise a single spotweld.
- \*INITIAL\_STRESS\_SECTION allows for stress initialization across a cross-section, which consists of solid elements.
- Added hourglass control type 7 for solid elements for use when modelling hyper-elastic materials.
- A new composite tetrahedron element made up from 12 tetrahedron is now available as solid element type 17.
- Tetrahedron type 13, which uses nodal pressures, is now implemented for implicit applications.
- Cohesive solid elements are now available for treating failure.
- Fixed consistency problem related to the type 17 tetrahedron that resulted in error terminations.
- Fixed time step calculation for type 17 tet (time step was too large).
- Fixed stress initialization for tetrahedral elements of element formulation 4.

## 2.19 THICK SHELL ELEMENTS

- Fixed materials 82 and 99 for type 3 thick shell elements.

### 3. ENHANCEMENTS & MODIFICATIONS MADE TO VERSION 971 R2 AFTER REVISION 7600.1116

Please note; some definitions have been included in multiple sections for convenience.

#### 3.1 ADAPTIVITY

- Fix option LCLVL in \*CONTROL\_ADAPTIVITY where LCLVL is a load curve controlling the adaptivity level.

#### 3.2 AIRBAGS

- Fix problem with load curve ID's and airbags.
- Fix load curve round-off problems related to \*MAT\_FABRIC and \*AIRBAG\_INTERACTION.
- Fix airbag bug related to blockage option (MPP only).

#### 3.3 ALE

- Fix bug in \*INITIAL\_VOLUME\_FRACTION (MPP only).

#### 3.4 CONSTRAINTS & SPOTWELDS

- Fix bug in \*RIGID\_TO\_DEFORMABLE\_INERTIA.
- Fix bug for \*ELEMENT\_PLOTEL affecting \*CONTACT\_SPOTWELD tying.
- Fix round-off problem with rigid bodies and prescribed rotational motion using the local option.
- Fix bug with circular butt welds not tying first/last node (MPP only).
- Fix to \*CONSTRAINED\_BUTT\_WELD when the nodes of the weld form a closed loop.
- Fix roundoff problem in rigid bodies in single precision calculations which is causing problems for customers in their transition from Radioss.
- Update behaviour of Toyota beam spot weld failure.

#### 3.5 CONTACT

- Fix minor bug in implicit tied contact that can result in negative eigenvalues.
- Fix bug for \*ELEMENT\_PLOTEL affecting \*CONTACT\_SPOTWELD tying.
- Fixed a potential memory error in segment-based (SOFT=2) contact.
- Modify AUTOMATIC\_TIEBREAK contact in MPP to better handle slave nodes that are initially below the contact surface.
- Fix MPP decomposition error if "silist" is used with any sliding interface other than the first one.
- Fix incorrect initial penetration warnings in edge-to-edge contact \*CONTACT\_AUTOMATIC\_GENERAL.

- Fix thick element check of SOFT=2 single surface contact.
- Fix MPP problem that caused segmentation violation in some problems with eroding contact involving shell elements.
- Minor fixes to automatic tiebreak contact (SMP only).
- Fix memory issue for eroding contact involving 10-node tetrahedral elements.
- Fix bug for SPH/SPH contact option. CONT=1 wasn't working.
- Fix guided cable contact to correct small penalty stiffness which led to large penetrations.
- Fix memory clobber that could cause incorrect contact stiffness in MPP if PENOPT 4 or 5 is turned on.
- Make SMP and MPP consistent in calculating stiffness of \*CONTACT\_SHELL\_EDGE\_TO\_SURFACE\_BEAM\_OFFSET.
- Fix so that zero length tied contacts work for \*CONTACT\_TIED\_SHELL\_EDGE\_TO\_SURFACE\_BEAM\_OFFSET.
- Fix translation bug for type 22 single\_edge contact (MPP only).

### 3.6 DATABASE & OUTPUT

- Eliminate segmentation fault associated with 2 surface force transducers (MPP only).
- Fix bug in d3part database if tshell and stress tensor are written in the database.
- Fix kinetic energy output to d3thdt database (MPP only).
- Fix deadlock while nodout filtering is on (MPP only).
- Fix secforc output to consider failed beam elements.
- Fix cross-section force calculation for thick shell formulations 2 and 3.
- Set pointer in intfor database correctly for each interface if force transducer exists (MPP only).
- Fix a potential MPP problem when 2-surface force transducers are used with segment based contact.
- Fix Rayleigh damping problem when energy calculation is active.
- Fix output issues with ESORT=2 option related to the deforc, elout, and d3plot files.
- Modify memory reporting for MPP so that the proper choices of memory and memory2 are reported.

### 3.7 EFG & SPH

- Fix bug in SPH forces calculation (MPP only).
- Fix memory problem affecting \*MAT\_ADD\_EROSION when used with fully integrated solids, type 2 and type 41 (EFG).
- Add new materials in EFG 3D.
- Implement \*MAT\_ADD\_EROSION for EFG element formulation 41.
- Fix bug in restart when SPH elements are used.

- Fix bug for SPH/SPH contact option. CONT=1 wasn't working.
- Enable \*MAT\_ADD\_EROSION for EFG solid type 41 and 42.
- Turn on Gauss integration scheme in EFG shell formulation 41.

### 3.8 IMPLICIT

- Fix minor bug in implicit tied contact that can result in negative eigenvalues.
- Fix bug in implicit dynamic relaxation related to thermal.
- Fix \*LOAD\_THERMAL\_LOAD\_CURVE when invoked during implicit dynamic relaxation.
- Fix related to generating the stiffness matrix for \*MAT\_HONEYCOMB.
- Fix implicit's treatment of \*BOUNDARY\_CYCLIC for rotating parts.

### 3.9 INPUT

- Fix bug in \*KEYWORD\_ID in which the jobid was always upper case.
- Eliminate false warning of empty segment set by reducing the tolerance for checking segments.
- Fix \*INITIAL\_STRESS\_SHELL where element offset is used instead of set offset.
- Fix prescribed acceleration problem with scale factor being applied twice.

### 3.10 LOADING

- Fix bug in \*LOAD\_MOVING\_PRESSURE.
- Fix \*LOAD\_THERMAL\_LOAD\_CURVE when invoked during implicit dynamic relaxation.

### 3.11 MATERIAL

- Fix for load curve round-off in \*MAT\_076, \*MAT\_083, \*MAT\_099, and \*MAT\_175.
- Fix minor problem for \*MAT\_024 with VP=1.
- Fix memory problem affecting \*MAT\_ADD\_EROSION when used with fully integrated solids, type 2 and type 41 (EFG).
- Add fix for 10-node tet elements comprised of \*MAT\_059.
- Make fixes to \*MAT\_037 and \*MAT\_186.
- Fix load curve round-off problems related to \*MAT\_FABRIC and \*AIRBAG\_INTERACTION.
- Fix bug related to iform=-14 in \*MAT\_FABRIC.
- Fix for load curve round-off in material types 76 and 175.

### 3.12 MISCELLANEOUS

- Stop 'too many subgroups' termination when there are eroding solids.

- Fix memory clobber related to bulk viscosity energy calculation.
- Fix bug in \*DEFINE\_FUNCTION.
- Fix jobid problem for \*PERTURBATION.
- Fix problems related to degenerate element sorting.
- Exit MPP job cleanly if NaN detected in any of the processors with option ISNAN on \*CONTROL\_SOLUTION.
- Fix memory clobber that could occur when \*DEFORMABLE\_TO\_RIGID is used in combination with beam elements.
- Fix MPP problem wherein partial slave node stiffness was used in rigid wall force calculation.
- Fix hourglass control type 6 problem with NCPU>1 for 2D solid elements.
- Fix problem in MPP whereby using more than 16 or 32 processors resulted in abnormally large amounts of time in rigid body processing, and hence poor scaling.
- Fix contact time step calculation to ignore infinitesimal masses of nodes created by \*INTERFACE\_LINKING\_SEGMENT. Using their mass was causing an infinitesimal solution time step to be invoked when \*CONTACT\_ERODING was used.

### 3.13 RESTARTS

- Fix MPP problem when deleting both contacts AND parts/elements during a small deck restart.
- Fix bug in restart when SPH elements are used.

### 3.14 SHELL ELEMENTS

- Fix bulk viscosity problem related to triangular shell elements.

### 3.15 SOLID ELEMENTS

- Add fix for 10-node tet elements comprised of \*MAT\_059.
- Fix 10-node tetrahedron element for large strain problems.
- Fix hourglass control type 6 problem with NCPU>1 for 2D solid elements.

### 3.16 THICK SHELL ELEMENTS

- Fix cross-section force calculation for TSHELL formulations 2 and 3.