

Many new capabilities were added during 2003-2005 to create version 971 of LS-DYNA. Initially, the intent was to quickly release version 971 after 970 with the implicit capabilities fully functional for distributed memory processing using MPI. Unfortunately, the effort required for parallel implicit was grossly underestimated, and, as a result, the release has been delayed. Because of the delay, version 971 has turned into a major release. Some of the new features, listed below, were also added to later releases of version 970. The new explicit capabilities are implemented in the MPP version and except for one case, in the SMP version as well.

Below is list of new capabilities and features:

- A simplified method for using the ALE capability with airbags is now available with the keyword \*AIRBAG\_ALE.
- Case control using the \*CASE keyword, which provides a way of running multiple load cases sequentially within a single run
- New option to forming contact: \*CONTACT\_FORMING\_ONE\_WAY\_SURFACE\_TO\_SURFACE\_SMOOTH, which use fitted surface in contact calculation.
- 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.
- 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
- Birth and death times for implicit dynamics on the keyword \*CONTROL\_IMPLICIT\_DYNAMICS.
- 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.
- Static implicit analyses in of a structure with rigid body modes is possible using the option, \*CONTROL\_IMPLICIT\_INERTIA\_RELIEF.
- 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.
- Solid element stresses in spot welds are optionally output in the local system using the SWLOCL parameter on the \*CONTROL\_SOLID keyword.
- 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.
- 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 function 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.
- Added new contact type \*CONTACT\_GUIDED\_CABLE.
- 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.
- Eight-character alphanumeric labels can now be used for the parameters SECID, MID, EOSID, HGID, and TMID on the \*PART keyword.
- 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.
- New keyword, \*ELEMENT\_SOLID\_T4TOT10 to convert 4 node tetrahedron elements to 10 node tetrahedron elements.
- 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 keyword option, SET, for \*INITIAL\_STRESS\_SHELL\_SET allows a set of shells to be initialized with the state of stress.
- New option allows the number of cpu's to be specified on the \*KEYWORD input.
- 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.
- Friction can now be defined between part pair using the \*DEFINE\_FRICTION input.
- 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.
- 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 vector, see \*DEFINE\_VECTOR, can be done by defining coordinates in a local coordinate system.
- 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.
- Added \*DEFINE\_SET\_ADAPTIVE to allow the adaptive level and element size to be specified by part ID or element set ID.
- Static rupture stresses for beam type spot welds can be defined in the keyword input, \*DEFINE\_SPOTWELD\_RUPTURE\_STRESS.
- Section properties can be define in the \*ELEMENT\_BEAM definitions for resultant beam elements using the SECTION option.
- Physical offsets of the shell reference surface can be specified on the shell element cards, see the OFFSET option on \*ELEMENT\_SHELL.
- File names can be located in remote directories and accessed through the \*INCLUDE\_PART 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-section are now available in the definition of beam integration rules, see \*INTEGRATION\_BEAM.
- The possibility of changing material types is now available for shells using the user defined integration rule, see \*INTEGRATION\_SHELL.
- The interface springback file created by using the keyword, \*INTERFACE\_SPRINGBACK is now optionally written as a binary file.
- An optional input line for \*KEYWORD allows the definition of a prefix for all file names created during a simulation. This allow multiple jobs to be executed in the same directory.
- 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.
- 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 spot weld 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 aluminum 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 modeling concrete.
  - \*MAT\_PLASTICITY\_COMPRESSION\_TENSION\_EOS for modeling 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
  
- User defined equations-of-state are now available.
- There is now an interface with the MOLDFLOW code.

- Damping defined in \*DAMPING\_PART\_STIFFNESS now works for the Belytschko Schwer beam element.
- 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 layouts is available with \*PART\_COMPOSITE
- The rigid body inertia can be changed in restart via \*CHANGE\_RIGID\_BODY\_INERTIA.
- 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.
- Added hourglass control type 7 for solid elements for use when modelling hyperelastic materials.
- Shell formulations 4, 11, 16, and 17 can now model rubber materials.
- Added a new seatbelt pretensioner type 7 in which the pretensioner and retractor forces are calculated independently and added.
- A new composite tetrahedron element made up from 12 tetrahedron is now available as solid element type 17.
- Shell thickness offsets for \*SECTION\_SHELL now works for most shell elements, not just the Hughes-Liu shell.
- 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.
- Two nonlinear shell elements are available with 8 degrees-of-freedom per node to include thickness stretch.
- Tetrahedron type 13, which uses nodal pressures, is now implemented for implicit applications.
- Cohesive solid elements are now available for treating failure.
- Seatbelt shell elements are available for use with the all seatbelt capabilities.
- Superelements can now share degrees-of-freedom and are implemented for implicit applications under MPI.
- A user defined element interface is available for solid and shell elements.
- Thermal shells are available for treating heat flow through shell elements.
- 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.
- 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 dbSor.
- \*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.
- Type 9 option is added in \*ALE\_REFERENCE\_SYSTEM\_GROUP to deal complex ALE mesh motions including translation, rotation, expansion and contraction, etc.
- 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.
- \*ALE\_MODIFIED\_STRAIN allows multiple strain fields in certain ALE elements to solve sticking behaviour in FSI. (MPP underdevelopment)
- \*ALE\_FSI\_PROJECTION is added as a new constraint coupling method to solve small pressure variation problem. (MPP under development)