General Guidelines for Crash Analysis in LS-DYNA®

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Modeling Guidelines for Crash Analysis

- Element Shapes
  - Avoid use of triangular shells, tetrahedrons, pentahedrons whenever possible (OK in rigid bodies).
  - ESORT=1 if triangular shells are present,*CONTROL_SHELL.
  - ESORT=1 if tetrahedrons, pentahedrons are present,*CONTROL_SOLID.

- Warping Stiffness in Shells
  - Warped shells are too soft.
    - For warped B-T shells, use *CONTROL_SHELL to set BWC=1 and invoke the more costly full projection for warping stiffness (PROJ=1) since drill projection inhibits rigid body rotation.
    - For fully-integrated shell ELFORM=16, set hourglass formulation IHG to 8 to invoke warping stiffness.

Modeling Guidelines for Crash Analysis

- Shells
  - Invoke invarient node numbering (INN=2 in *CONTROL_ACCURACY) so that results are insensitive to the order of the nodes in the element connectivity.
  - Shell thickness update (ISTUPD in *CONTROL_SHELL) is generally not needed for crash analysis (req'd for metal forming).
    - If thinning is needed, invoke selectively (by parts) via PSSTUPD and use more stable ISTUPD=4
  - Use minimum of 3 integration points through the thickness (NIP in *SECTION_SHELL) for shell parts undergoing plastic deformation.
  - Set shear factor in *SECTION_SHELL to theoretical value of 5/6 or invoke Laminated Shell Theory by setting LAMSHT=3 in *CONTROL_SHELL.
  - Turn on bulk viscosity for shells by setting TYPE = -1 *CONTROL_BULK_VISCOSITY
- Solids
  - Use ELFORM=1 for solids and include appropriate HG control

Modeling Guidelines for Crash Analysis

- Hourglass Control
  - If using *CONTROL_HOURGLASS, define part-specific *HOURGLASS cards to overwrite the global hourglass definitions where appropriate.
    - Be careful when importing validated barrier/head models
  - Recommend stiffness hourglass control, IHQ=4, with hourglass coefficient QM = 0.03 for metal and plastic parts.
  - Recommend HG type 6 with HG coefficient between 0.5 and 1.0 for foams and rubbers
    - In soft materials, stiffness-based hourglass control (types 4 and 5) likely causes overly stiff response even with a reduced hourglass coefficient.

Modeling Guidelines for Crash Analysis

- Materials
  - When including strain rate effects in plasticity models, set VP=1.
    - Uses plastic strain rate rather than total strain rate.
    - Results in smoother response
  - Stress-strain curves should be smooth, especially for foams.
  - Mass of null shells and null beams is included in total mass.
    - Unless additional mass is intentional, set density of null shells and beams to a small value.
  - Curves defining constitutive data should have abscissa values in the anticipated working range. Curves will be extrapolated by LS-DYNA® if necessary.

Modeling Guidelines for Crash Analysis

- Connections
  - Nodal rigid bodies
    - Avoid 1-noded RB's and nodal rigid bodies with numerically insignificant inertia as these rigid bodies are deleted and a warning is issued to the *d3hsp* file.
  - Joints
    - Joint node pairs should be a reasonable distance apart.
    - When increasing joint penalty factor to take out 'slop' in penalty-based joint, the time step scale factor may need to be reduced to avoid instability.

Modeling Guidelines for Crash Analysis

- Connections
  - Discrete springs
    - Spring nodes cannot be massless.
    - If _NONLINEAR spring material is used, define stiffness in compression and tension.
    - Use only N1 to N2 orientation.
  - Deformable spotwelds
    - Avoid "free/suspended" spotwelds.
    - Look out for spotweld nodes that are not tied (see warnings in d3hsp).
    - Exclude spotwelds from contact (automatic if *MAT_SPOTWELD is used)
    - Invoke stiffness damping in shells if using *CONTACT_SPOTWELD_TORSION
    - Solid spotwelds show promise.
      - Less sensitive to spotweld placement
      - Beam spot welds can be converted to solid spot welds automatically using *CONTROL_SPOTWELD_BEAM

Modeling Guidelines for Crash Analysis

- Rigid Bodies
  - Refined mesh of rigid bodies encouraged.
    - Added expense is minimal.
    - More realistic mass properties and distribution of contact forces.
  - Specify reasonable elastic constants for *MAT_RIGID, e.g., those of steel.
    - Affects contact stiffness unless SOFT=2.
  - Do not impose constraints on nodes of rigid bodies. Impose constraints on card 2 of *MAT_RIGID or using the _SPC option for the *CONSTRAINED_NODAL_RIGID_BODY command.

Modeling Guidelines for Crash Analysis

- Initial Velocity
  - Be careful with rigid body initial velocities.
    - There is a hierarchy to the commands that specify initial velocity for rigid bodies: *INITIAL_VELOCITY_RIGID_BODY, *INITIAL_VELOCITY with IRIGID flag on, *PART_INERTIA, *INITIAL_VELOCITY_GENERATION
    - If initial velocity of rigid bodies is inexplicably off, use double precision or use *INITIAL_VELOCITY_RIGID_BODY command.
  - Make final check of initial velocity with a plot of velocity vectors at time = 0.
- Parallel Processing
  - For SMP, turn on consistency flag with ncpu=-|#procs| on execution line.

Modeling Guidelines for Crash Analysis

- Contact
  - Take care to account for shell thickness when generating the mesh.
  - Avoid redundant contact definitions.
  - Use only AUTOMATIC contacts.
  - Increase contact thickness for very thin shells to prevent release of contact.
  - Use of IGNORE=2 or SOFT=2 is encouraged for contact in cases where small initial penetrations are reported.
  - Use of SOFT=1 is preferred over SOFT=0, especially in treating contact between dissimilar materials.
  - Use SOFT=2 for contact surfaces with sharp corners.
  - Use AUTOMATIC_GENERAL for beam-to-beam contact.

Modeling Guidelines for Crash Analysis

- Postprocessing
  - Animate results to check for nonphysical behavior, for example, parts noticeably penetrating other parts.
  - Check energies in *glstat* and *matsum*
    - Use *CONTROL_ENERGY to turn on computation of relevant energy values.
    - Energy ratio should remain close to 1.0.
    - Hourglass energy < 10% of peak internal energy.
    - If no contact friction, contact energy in *glstat* should be elastic and thus near zero when parts are no longer in contact.
    - If contact friction is nonzero, contact energy should be positive and not necessarily small.
  - When using mass scaling, check added mass in *glstat*. Added mass sensitivity study is suggested to justify use of added mass.