General Guidelines for Crash Analysis in LS-DYNA

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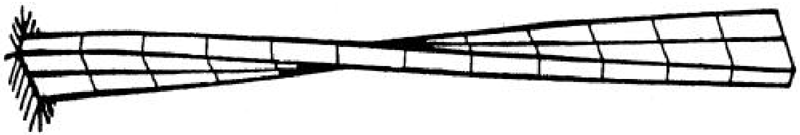
Modeling Guidelines for Crash Analysis

- **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**



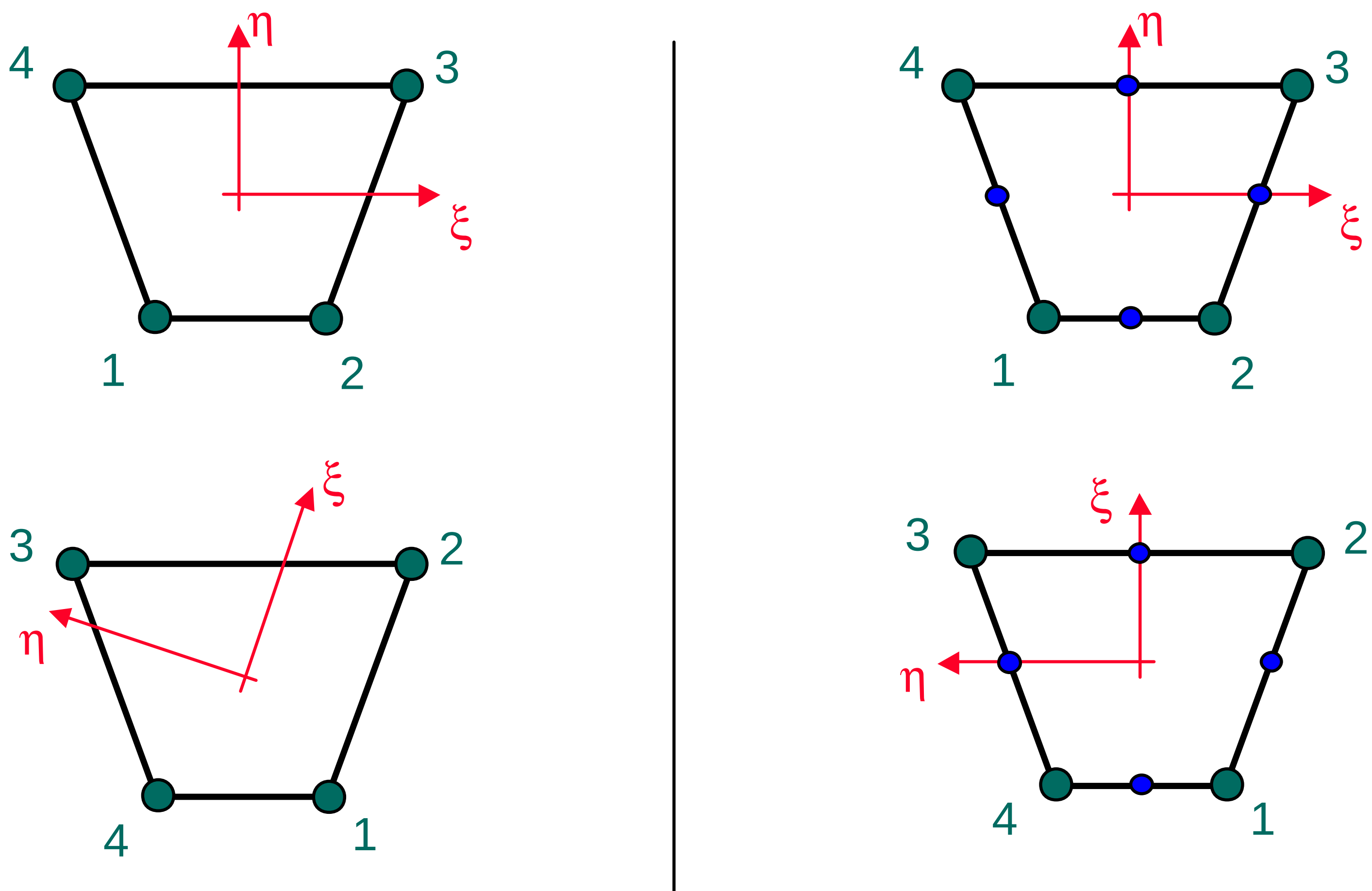
  - Warped shells are too soft.
    - For warped B-T shells, set BWC=1 and invoke the more costly full projection for warping stiffness (PROJ=1) since drill projection inhibits rigid body rotation.
    - For fully-integrated shell ELFORM=16, set hourglass formulation IHG to 8 to invoke warping stiffness.

Modeling Guidelines for Crash Analysis

- ## Shells
  - Invoke invarient node numbering (*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 need for crash analysis (req'd for metal forming).
  - Use minimum of 3 integration points through the thickness (NIP) for shell parts undergoing plastic deformation.
  - Set shear factor in *SECTION_SHELL to theoretical value of 5/6.
  - Turn on bulk viscosity for shells via *CONTROL_BULK_VISCOSITY

- ## Solids
  - Use ELFORM=1 for solids and include appropriate hourglass control

Invariant Node Numbering



default

invariant node numbering invoked

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 viscosity-based hourglass control for foams and rubbers (IHG=2 or 3) or hourglass formulation 6
    - In soft materials, stiffness-based hourglass control (IHG=4 or 5) 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.

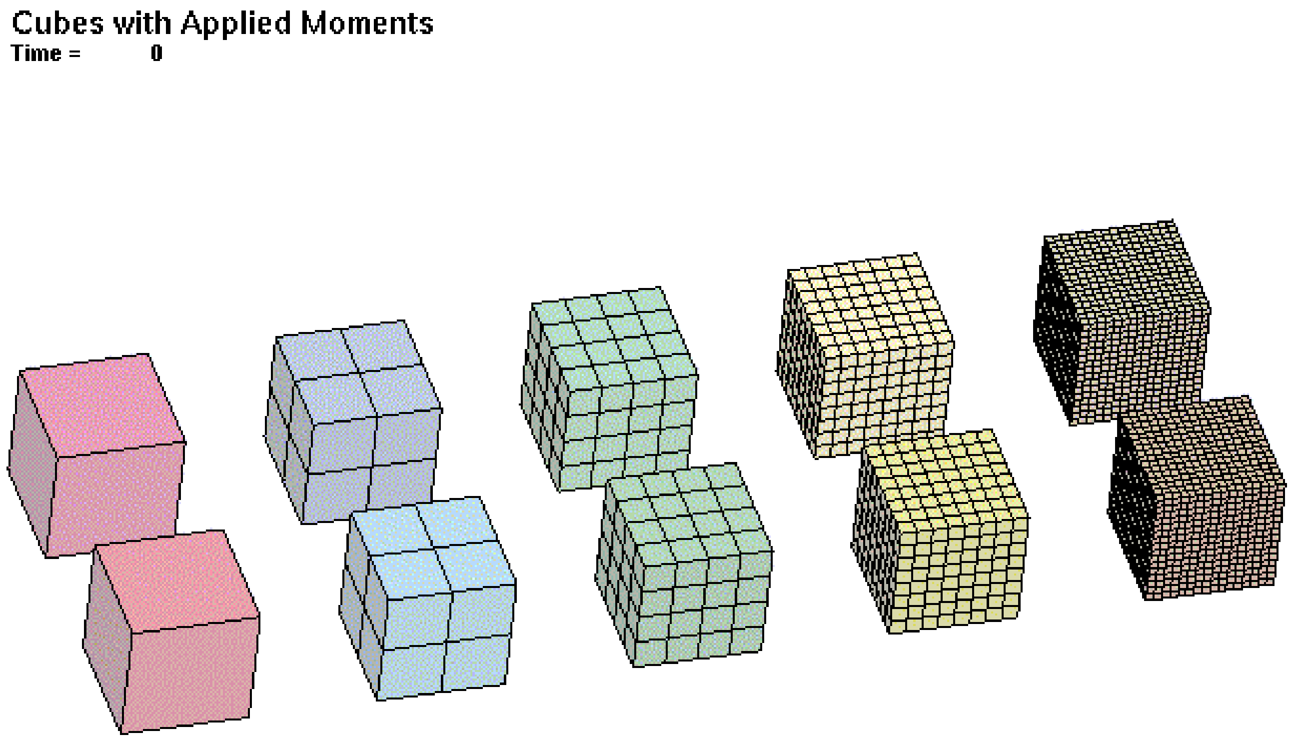
Modeling Guidelines for Crash Analysis

- **Connections**
  - Discrete springs
    - Spring nodes cannot be massless.
    - If NON_LINEAR 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.
      - Pro: Less sensitive to spotweld placement
      - Con: No automatic spotweld generation

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.

Inertia Considerations: Example



shells

solids

MMI: Mass Moment of Inertia
units: mm, kg, ms

Number of elements		Element length	LS-DYNA calculated MMI		Actual MMI (solid)	% Error solids
shells	solids		shells	solids		
6	1	25	38.38	38.38	12.79	200%
24	8	12.5	25.59	19.19	12.79	50%
96	64	6.25	22.39	14.39	12.79	12.5%
384	512	3.125	21.59	13.19	12.79	3.1%
1536	4096	1.5625	21.39	12.89	12.79	0.8%

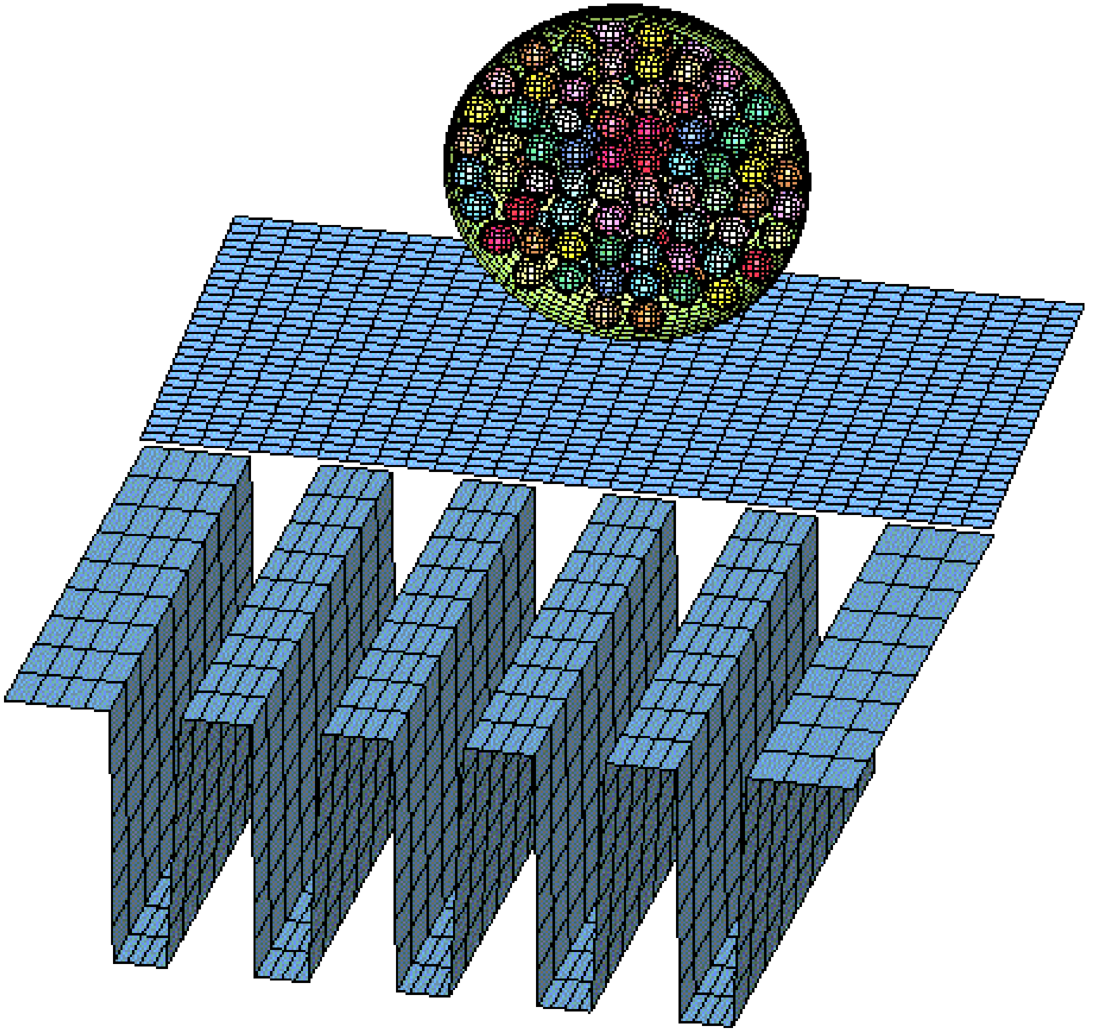
Modeling Guidelines for Crash Analysis

- **Initial Velocity**
  - Be careful with rigid body initial velocities.
    - *PART_INERTIA supercedes all other initial velocity commands.
    - If initial velocity of rigid bodies is inexplicably off, use double precision or use *INITIAL_VELOCITY_RIGID command.
  - Make final check of initial velocity with a plot of velocity vectors at time = 0.

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.
  - Premature nodal release from contact may lead to inconsistent answers. Increase contact thickness for very thin shells
  - Use of IGNORE=1 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.

Segment-Based Contact (SOFT=2)



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 relatively small.
    - If contact friction is nonzero, contact energy should be positive and not necessarily small.
  - System added mass should be < 1% of physical mass (check GLSTAT)

Modeling Guidelines for Aerospace Analysis

- **Automotive Crash guidelines are a good start.**

- **Differences in Automotive Crash and Aerospace Impact?**
  - Impact velocities and thus strain rates are higher in Aerospace applications.
    - Material strain rate effects
    - Material damage/failure/erosion
  - Aerospace materials are generally lighter, stiffer, more complex.
  - …

Modeling Guidelines for Aerospace Impact

- **Additional guidelines for Aerospace impact**
  - Time Step
    - Reduce time step scale factor to 0.6 or 0.7.
  - Hourglass Control
    - Look at viscous-based hourglass control as first alternative.
    - Use type 1 hourglass control with hourglass coefficient=1.E-3 for fluids.
  - Bulk Viscosity
    - Increase bulk viscosity coefficients by a factor of 10 for bird material.

Modeling Guidelines for Aerospace Impact

- **Additional guidelines for Aerospace impact**
  - Contact
    - When elements are eroded, use *CONTACT_ERODING with SOFT=1.
      - Eroding_nodes_to_surface for Lagrangian bird strike.
      - Eroding _single_surface otherwise
    - Retain mass of eroded elements via ENMASS in *CONTROL_CONTACT
  - Materials
    - Include strain rate effects if data is available.
    - For sandwich composites, invoke laminate shell theory (LAMSHT in *CONTROL_SHELL).
  - …

Effect of Deleted Nodes on Contact