Modeling of Impact Pendulum

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MEG 795

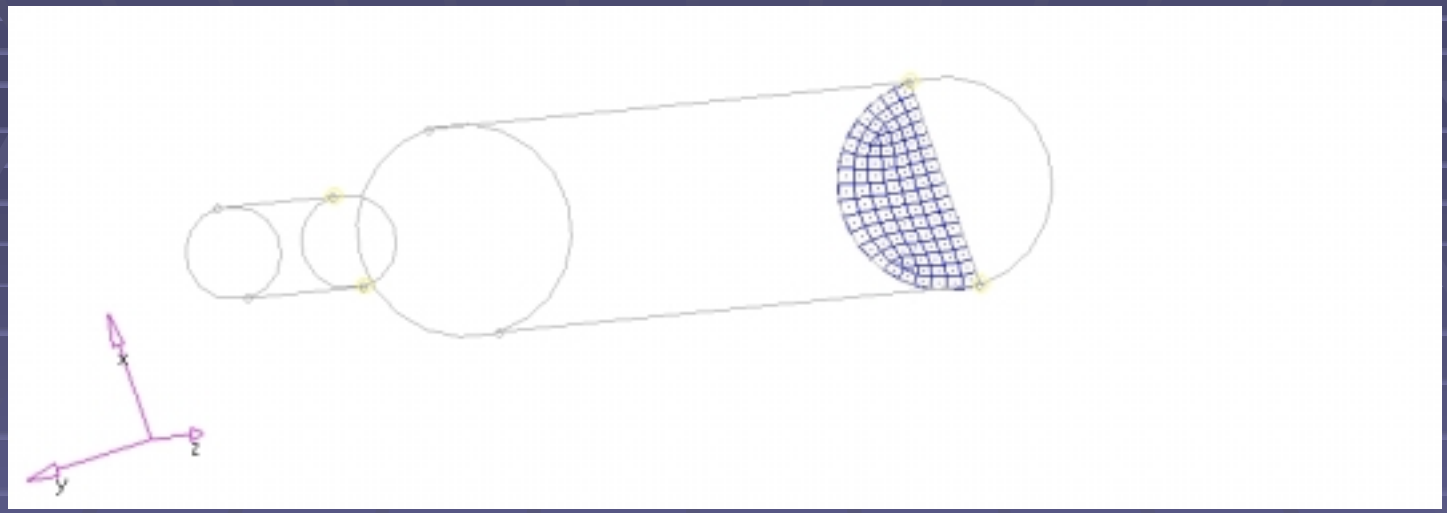
12/12/03

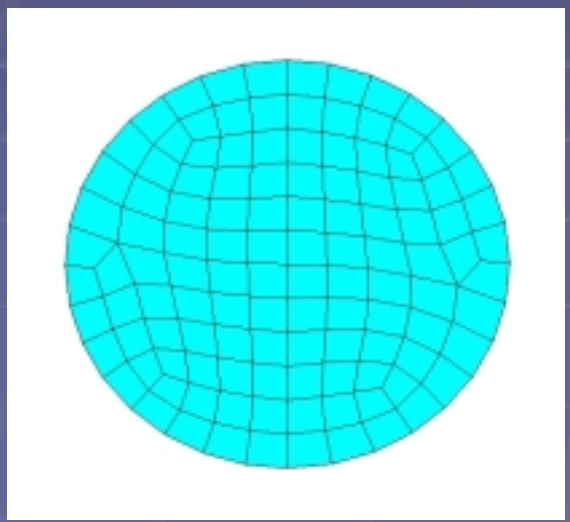
Objectives

- Simulate impact of steel projectile and pendulum at 2112 in/s (120 mph).
- Compare model to calculations.
- Compare peak acceleration of model to measured values during real life testing.

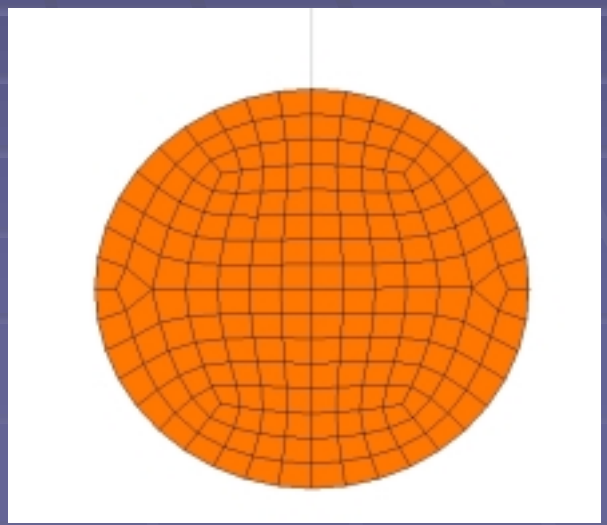
Test Setup

Meshing





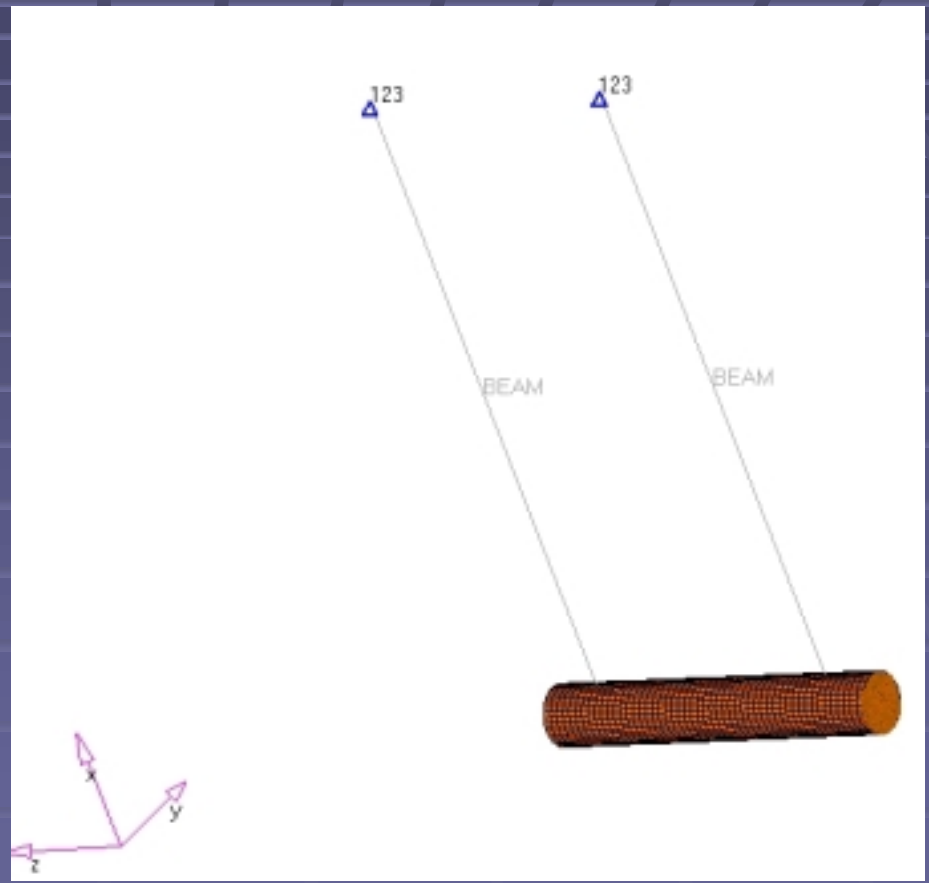
Slug Mesh



Pendulum mass mesh

Modeling Steel Cables

- Modeled as beam elements
- Fixed nodes at top position of cables
- Created nodes at attachment to mass
- Beams created between two nodes



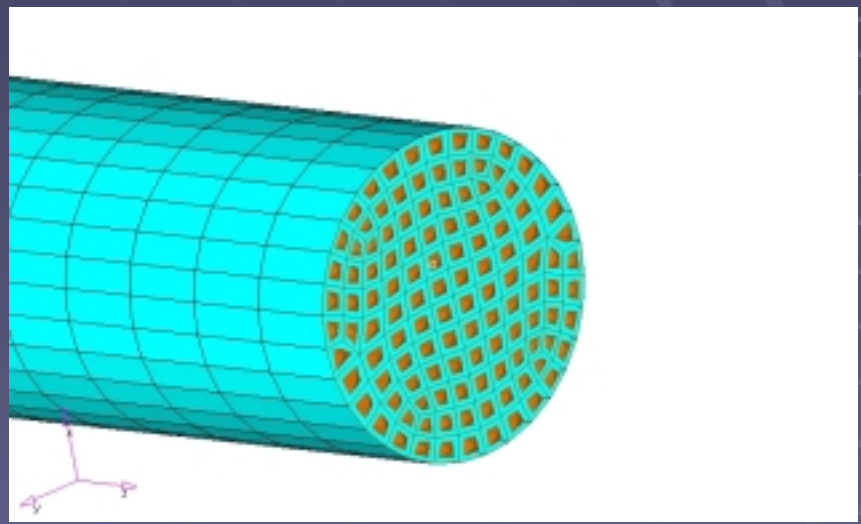
Initial Material Card

- Units (lb_f, lb_m, in, sec)
- MAT_PLASTIC_KINEMATIC
- AISI 1017 Steel
  - Density (lb/in3) 0.284
  - Young's Modulus (psi) 29700000
  - Poisons Ratio 0.3
  - Yield Strength (psi) 49300
- Strain rate effects
  - SRC = 0.5
  - SRP = 1.5

$$\sigma_y = \left(1 + \frac{\dot{\varepsilon}^{\frac{1}{p}}}{C}\right) \cdot \left(\sigma_o + \beta E_p \cdot \varepsilon_{eff}^{\,p}\right)$$

Contact Card

- Surface to surface
- Segment Sets for slug and mass
- Pendulum mass set to master
- Scale factor of 10 for slave and master



Measured Acceleration and Impact Equations

Measured acceleration of pendulum mass: 1.50472e6 in/s^2

projectile mass: $m_a := 5lb$

pendulum mass: $m_b := 110lb$

coeff of restitytion: $e := 0.6$

initial velocity: $v_{a1} := 2112\frac{in}{s}$

$v_{b1} := 0$

momentum equation: $m_a \cdot v_{m1} + m_b \cdot v_{b1} := m_a \cdot v_{a2} + m_b \cdot v_{b2}$

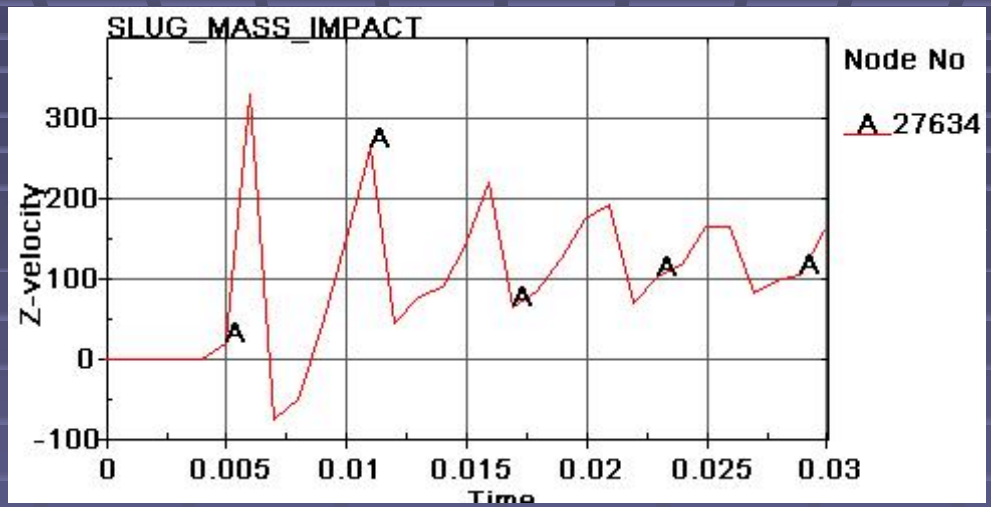
coefficient of restitution equ: $e := \frac{v_{b2} - v_{a2}}{v_{a1} - v_{b1}}$

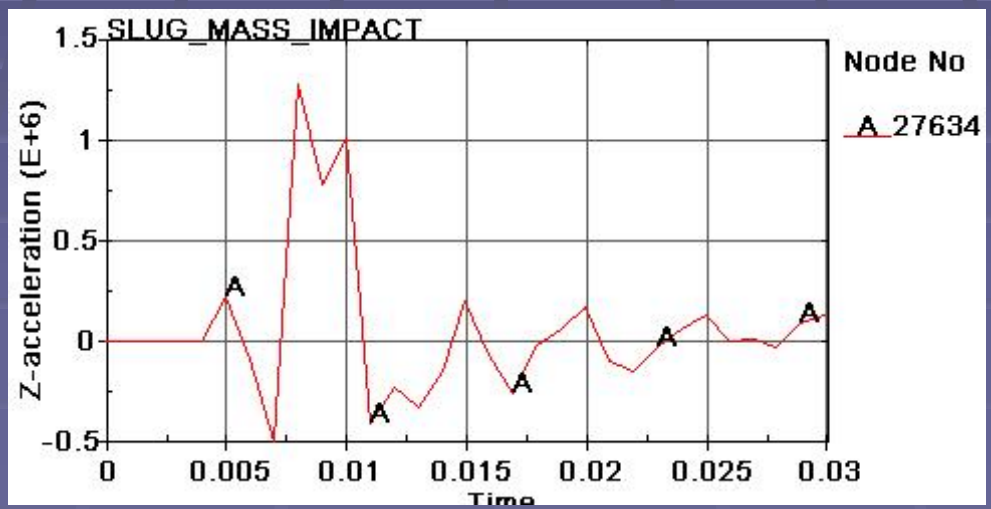
solving the equations gives: $v_{a2} := -1120.3\frac{in}{s}$ and $v_{b2} := 146.9\frac{in}{s}$

Initial Model Results

- Slug
  - Peak velocity after impact = -441 in/s
  - Relative velocity error = 60%
- Pendulum Mass
  - Peak velocity after impact = 330 in/s
  - Relative velocity error = 125%
  - Peak acceleration after impact = 1.288e6 in/s^2
  - Relative acceleration error = 14.4%

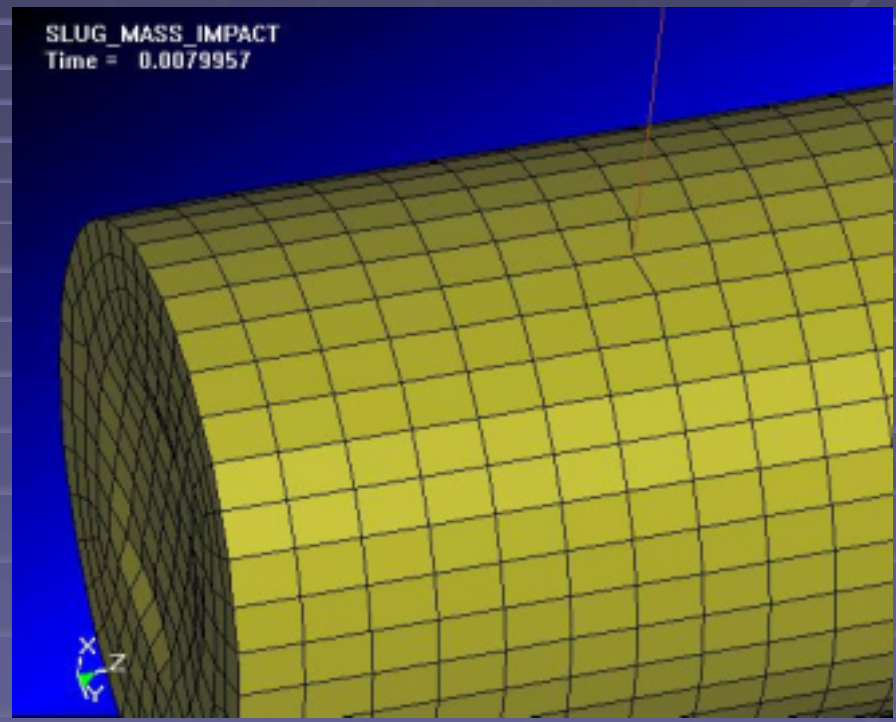
Initial Mass Velocity and Acceleration Plots





Problems with Initial Model

- Oscillation of pendulum mass
- Unknown materials
  - Different properties for the slug and mass
- Incorrect deformation

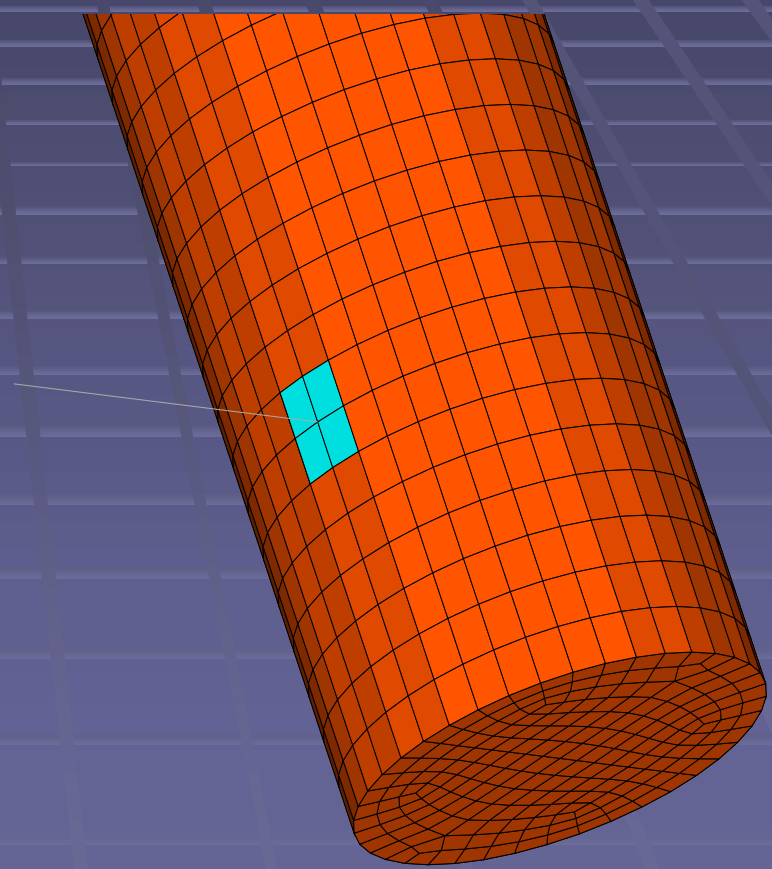


Second Model

- Stiffened elements around cable attachments
- Applied global damping
- Removed strain effects from material card
- Scaled yield stress

Stiffened Elements

- Material Card
- *MAT_PLASTIC_KINEMATIC
- $HMNAME MATS
  3beam_connect_elem_mat
- 3 0.284600000000. 0.3 3500000.0



Damping

- Damping constant was determined based on lowest frequency mode with the following equation.
  - $d = 2*\omega_{min}$
- FFT analysis displayed a mode at 5 Hz.
- The initial damping constant was 60
  - *DAMPING_GLOBAL
  - $ LCID VALDMP
  - 0 60

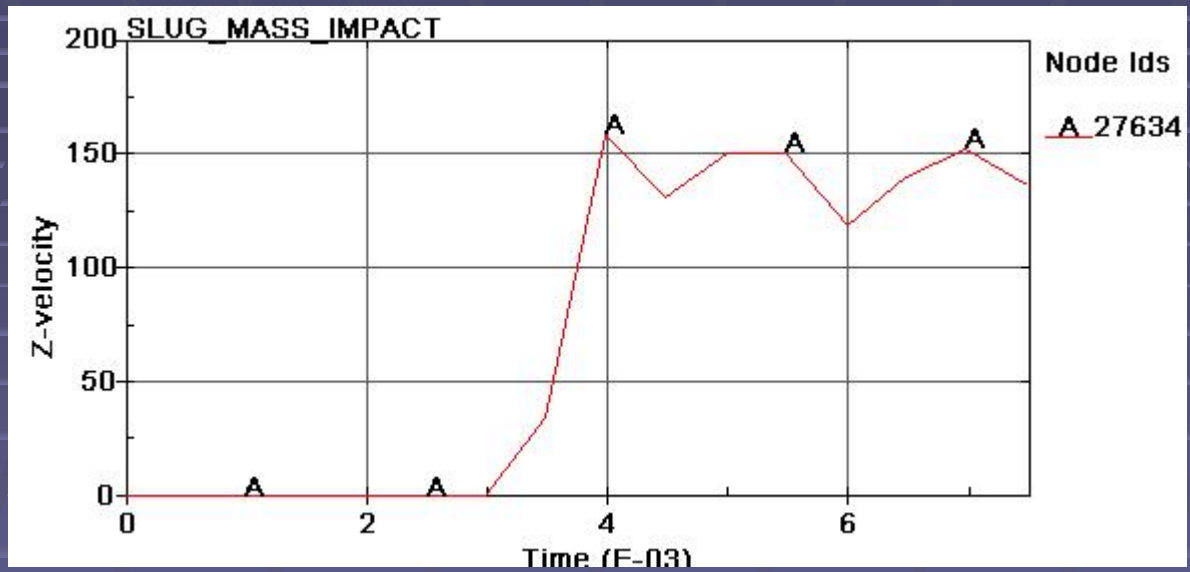
Material Cards

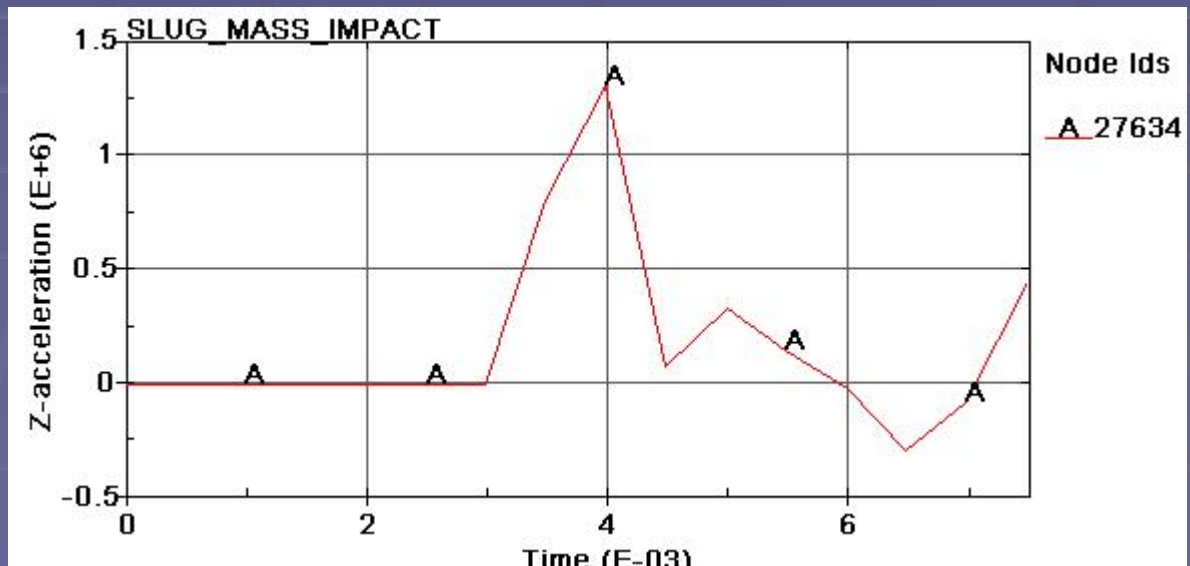
- Slug
  - *MAT_PLASTIC_KINEMATIC
  - $HMNAME MATS 1steel
  - 1 0.28429000000.0 0.3 4250000.
- Mass
  - *MAT_PLASTIC_KINEMATIC
  - $HMNAME MATS 3beam_connect_elem_mat
  - 3 0.284600000000. 0.3 3500000.0

Second Model Results

- Slug
  - Velocity = 1315 in/s
  - Relative error = 17.4%
- Mass
  - Velocity = 159 in/s
  - Velocity error = 8.2%
  - Acceleration = 1.3073E6 in/s^2
  - Acceleration error = 13%
- Slug deformation
  - Diameter increased by 0.3in
  - Live fire test diameter increased by 0.1in
  - Relative error = 9.5%

Second Model Plots for Mass





Conclusion

- Damping and element stiffening helped decrease oscillation.
- Scaling yield stress produced good results; however, it made material properties unrealistic.
- Material models needs to be benchmarked.