8/14/02

Impact Calculations

- Assess vulnerability of storage casks to aircraft threats
- Outcome of analysis
  - Determine momentum imparted to cask and resultant cask velocity
  - Potential failure/breach of cask
  - Determine representative force-time loading on cask
- Tools
  - CTH – production code
  - Zapotec – in-development

CTH Impact Calculations

- As a first step, consider "simplified" aircraft impacting cask without underlying concrete pad
  - A/C composed of center fuselage, center fuel tank, and front wheel
    - Main landing gear not modeled due to lack of placement info
  - "Floating" cask implies frictionless contact with pad

- CTH Problem Setup
  - Nominal 10 cm resolution throughout mesh
  - Finer mesh (4 cm resolution) in the initial impact region
  - Mix = 3 option, results in "sticky" interface
  - Some excursions to assess material model inputs
    - Focus on cask concrete and fuselage materials

CTH Impact Calculations
Description of Calculations

- CTH-4
  - Fuselage modeled as "porous" aluminum
    - P-alpha model (ρ_{porous} = 0.253 g/cc ρ_{crush} = 0.514 g/cc)
  - Cask concrete model supplied by Marlin Kipp
    - Fit to SAC-5 concrete (Small Aggregate, Chert – 5000 psi)

- CTH-4a
  - Fuselage modeled as "porous" aluminum
  - Cask concrete model supplied by Dave Crawford
    - Smeared model tuned to engine impact experiments (Ref: Sugano, et.al.)

- CTH-6a
  - Fuselage modeled using standard Mie-Gruneisen EOS (ρ_o = 0.253 g/cc)
  - Cask concrete model supplied by Marlin Kipp

- CTH-RGD
  - Same as CTH-4, but rigid target (modeled as steel slab)

CTH Impact Calculations

CTH-4a Results

Ex2

Portion Ex2

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CTH Impact Calculations

CTH-4a Results

CTH Impact Calculations

Cask Velocity and Applied Force

Velocity (m/s)

Portions Ex 2

CTH Impact Calculations

Change in Impactor Momentum

Ex2

Portions Ex2

CTH Impact Calculations

Concluding Remarks

- Effect of underlying pad on cask kinematics cannot be modeled with CTH
- Frictional effects cannot be explicitly modeled with CTH
- Next CTH calculation
  - Model impact with full A/C (i.e., include wings, wing fuel tanks, etc.)
  - Goal: Investigate effects of added mass contribution

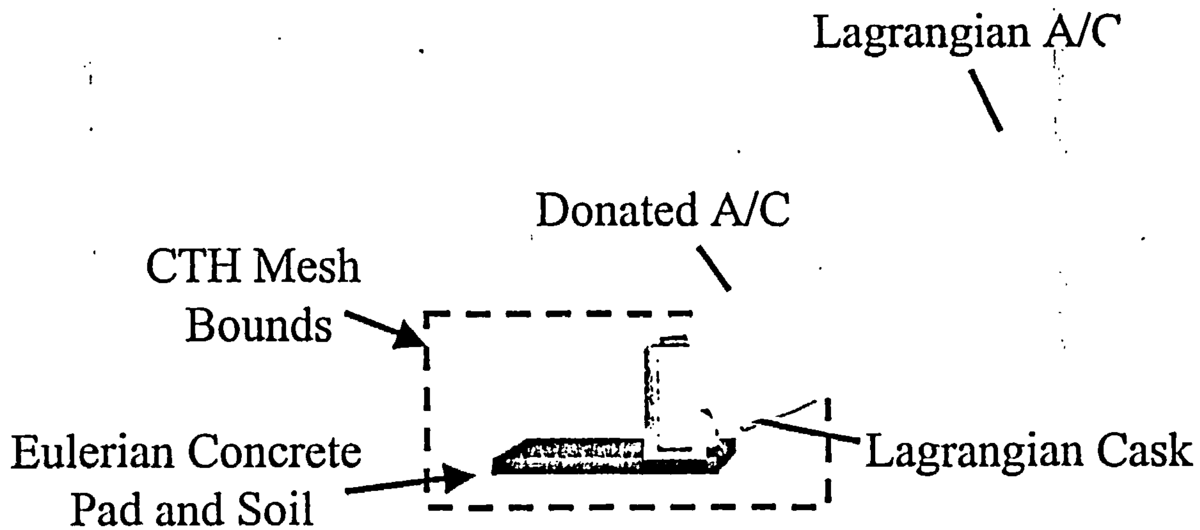
Zapotec Impact Calculations

- Evolution of Zapotec solution approach
  - Lagrangian aircraft / Lagrangian cask
    - A/C fuselage modeled using true shell elements
    - Donate portions of Lagrangian A/C to CTH mesh to assure continued interaction between threat and target
    - Shell element contact posed many challenges
  - Alternate approach - Lagrangian “in-flow” problem
    - Donate portions of Lagrangian A/C to CTH mesh based upon a coordinate-based element death criterion
    - Avoids Lagrangian contact between threat and target
    - Potentially a faster, more robust approach

Zapotec Impact Calculations

Problem Development for Cask Impact

- Tet-meshed A/C "flows" into CTH mesh
- Portions of A/C donated to CTH
- Donated parts interact with target
- Target composed of Lagrangian and Eulerian materials



Zapotec Impact Calculations

- Model same "simplified" A/C impact problem
  - Consider CTH results as the "truth"
    - Best we can do without experimental data
  - Provide some means for Zapotec algorithm verification

- Zapotec Problem Setup
  - Lagrangian Cask
    - Karagozian and Case (K&C) concrete model used for cask
  - Lagrangian A/C donated to CTH mesh
    - Fuselage modeled as "porous" aluminum
  - Friction between A/C and cask modeled

Zapotec Impact Calculations

Comparisons with CTH Results

Ex 2

Portions Ex 2

~~UNCLASSIFIED CONTROLLED INFORMATION~~

Zapotec Impact Calculations

Comparisons with CTH Results at 5 msec

Ex 2

portions Ex 2

CTH

Zapotec

~~UNCLASSIFIED CONTROLLED INFORMATION~~

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Zapotec Impact Calculations

Comparisons with CTH Results at 40 msec

Ex 2

Portions Ex 2

CTH Zapotec

Zapotec Impact Calculations
Concluding Remarks

- Why the difference between CTH and Zapotec?
  - Zapotec is not properly updating the CTH material state data following donation
  - Non-trivial effort to ensure consistency of material states when using complex material models

- Potential work-around
  - Model fuselage material using standard Mie-Gruneisen EOS as with CTH-6a calculation

Future Efforts

- Zapotec has greatest potential for modeling A/C impacts
  - Affords capability to model oblique A/C impacts, detailed cask modeling and response assessment, frictional effects, etc.
  - Today's big hurdle
    - Transfer of state data between codes and consistency of material response

- Start validation for engine impact problems
  - Sugano, et. al., "Local Damage to Reinforced Concrete Structures Caused by Impact of Aircraft Engine Missiles, Part 1. Test Program, Method and Results", *Nuclear Eng. Design*, Vol. 140, pp. 387-405 (1993)
  - Addresses impacts against reinforced concrete structures
  - Transfer of state data will be an issue for Zapotec

- Comparison calculation with Riera loading
  - Aircraft impact against a containment wall
  - Help "shakedown" Zapotec for large impact problems

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Results at 5 msec of analysis time
Concrete Cells

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Engineering Sciences Center

Ex 2

Portions Ex 2

Preliminary results show