A Blast Model Comparison between Hydrocode and CFD

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November 7, 2012
Agenda

- Background
- Assumptions
- Problem
- The Codes
- The Models
- Results
- Observations and Differences
- Conclusions
- Recommendations
Background

- Blast or blast wave propagation modeling usually conducted using hydrocode
- CFD codes have the capability to do blast analysis
- Questions are asked
  - Are the results the same or similar?
  - Is one type of analysis superior to another?
  - Are there advantages to running one over the other?
Assumptions

- “Blast” equivalent to 20 kg TNT
- Initial high-pressure volume of air to avoid complexities of HE detonation
- Several rooms or spaces to provide a meandering path for the blast
- Include hallways or corridors
- Air at STP filled remaining volume of rooms
- Walls modeled as voids
- No escape pathways or boundaries
- Codes set up for model equivalency – dimensions, mesh, etc.
- 2D proof of concept for Autodyne and Fluent was previously run
Problem

- Develop a problem that would challenge both codes
- Show differences in model, setup, run time, data analysis, accuracy
- Create models so they would be as “identical” as possible for each code
- Minimize factors that would contribute to initial differences
  - Explosion
  - Cell size
Model with Dimensions

Notes:
• Several rooms or spaces to provide a meandering path for the blast.
• Hallways or corridors
• Air is medium
• Walls modeled as voids
• No escape pathways or boundaries
The Codes

Hydrocode

- ANSYS Autodyne®
  - Physics-based wave propagation code
  - A fully coupled Eulerian and Lagrange explicit dynamics simulation software
  - An explicit analysis tool for modeling nonlinear dynamics of solids, fluids and gases
  - Used for solving large deformation, finite strain transient problems that occur on a very short time scale, e.g., explosions, blast, shock, impact, penetration
  - Tightly integrates the pre-processing, post-processing and analysis modules

CFD

- ANSYS Fluent®
  - Physics-based computational fluid dynamics simulation code
  - Subsonic to hypersonic; compressible and incompressible flow; laminar and turbulent; steady state to transient
  - Tightly integrates pre-processing, meshing, and post-processing with simulation
  - Highly parallel and scalable
Model as Built in Autodyne

Notes:
• 100 mm mesh
• 1 m wide corridors
• Ambient air at 14.7 psi
• 2000 psi air volume at t=0
• Air not allowed to escape through boundaries

Height = 3 m
Fluent Model

Notes:
- 100 mm mesh
- Ambient air at 14.7 psi
- 2000 psi air volume at t = 0
- Air not allowed to escape through boundaries
- Dimensions identical to Autodyne model
Pressurized Volume

Notes:
- 100 mm mesh
- Ambient air at 14.7 psi
- 2000 psi air volume at t = 0
- Air not allowed to escape through boundaries
Data Collection

Hydrocode

– ANSYS Autodyne®
  – Gauges put in model to collect data while the model runs – data collected at times predetermined by user
  – Screen shots of model generated at time intervals predetermined by user
  – P-t curves generated
  – Overpressure screen shots generated

CFD

– ANSYS Fluent®
  – Data for model saved every 0.05 ms of flow time
  – Large data files generated that can be used to produce data plots and screen shots after the model has completed running
  – P-t curves generated
  – Overpressure screen shots generated
Gauge Locations

Notes:
• Gauges at 0.85 m off floor
• Fluent data was collected at same XYZ locations
Autodyn – Fluent Comparison of Pressure Contours

Note: At each time interval, contour scales are identical.
Autodyn – Fluent Comparison of Pressure Contours

Note: At each time interval, contour scales are identical.
Autodyn – Fluent Animations

Fluent
- 0-50 ms
- 0.05 ms

Autodyn
- 0-50 ms
- 0.061 ms increments
Autodyne – Fluent P-t Comparison

Significant P-t divergence at early times
Autodyn – Fluent P-t Comparison

![Graph showing Autodyn and Fluent pressure comparison over time.](image)

**Graph Details:**
- **X-axis:** Time, ms
- **Y-axis:** Pressure, psig
- **Comparative Lines:**
  - Fluent 9 (black line)
  - Autodyn 9 (red line)
- **Key Points:**
  - Initial pressures: 67 psi and 57 psi
  - Pressure convergence at late times, Δ = 0-2 psi
  - P-t convergence at late times

*Note: The image contains a graph with data points and lines indicating the pressure comparison between Autodyn and Fluent over time.*
Autodyne – Fluent P-t Comparison

Autodyne - Fluent Pressure Comparison - Gauge 13

P-t convergence at late times

Δ~0 psi

Δ~8 psi
Autodyne – Fluent P-t Comparison

Very close P-t at late times

Δ~0.5 psi
Autodyne – Fluent P-t Comparison

P-t behavior very similar, with late-time divergence

Δ≈3 psi
Observations

- Both hydrocode and CFD can handle pressure wave propagation
- General agreement in P-t, especially at longer time
- Fluent $\Delta t$ was an issue, especially at early times (0-15 ms)
- Fluent runtime was about 2X longer from 15-200 ms
- Autodyne optimized for running this class of problem efficiently
- Model very easy to build in Fluent
- Fluent has a very powerful mesh generator
- Fluent produces GB++ of data
- Both Fluent and Autodyne have comparable graphics capabilities
Conclusions

- Both hydrocode and CFD can run for blast wave propagation problems
- Hydrocode (Autodyne) is optimized for this type of analysis
- CFD (Fluent) has significant advantages
  - Importing and meshing complex geometry
  - Parallelization
  - Post processing
  - Types of data captured
Recommendations

- Use hydrocode for this type of analysis
  - Unless there are compelling reasons to do otherwise

- Use CFD when
  - Runtime not a factor
  - Availability of many processors
  - Complex geometry that would be difficult to mesh and run with hydrocode
  - Analysis requirements

- Optimize Fluent variable settings
  - Timestep iteration
Questions

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Backup Slides
## Runtime Comparison

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<th>Code</th>
<th>100 mm</th>
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<td>Autodyne DP (15 ms)</td>
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<td>Autodyne DP (15 – 200 ms)</td>
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<td>Fluent DP (15 ms – 200 ms)</td>
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Fluent has longer run times, but is also saving massive amounts of data.