Predictive Simulations of Crash Impacts Using HPRC: The Short Radius Example

-- Akram Abu-Odeh
Acknowledgment

• Research Team (Past and Present)
  • Katherine McCaskey
  • Michael Bychkowski,
  • Matthew Spencer,
  • Ryan Allcorn
  • Ivan Liu,
  • Marsha Palasota,
  • Kelly Ha
  • Brett Jackson
  • Conor Mitchell

• Texas Department of Transportation (TxDOT)
• Texas A&M Transportation Institute (TTI)
• High Performance Research Computing (Texas A&M University)
What are Roadside Safety Devices?

- Roadside Safety Devices: used to shield, contain and redirect vehicles away from roadside hazards

- Roadside Hazards include both fixed objects and non-traversable roadside features
Evaluation Methodologies

- Testing standards have evolved over the course of history based on crash test data
  - Vehicle fleet
  - Roadway Velocity
  - Departure/Encroachment angle

- The Manual for Assessing Safety Hardware (MASH) is the new state of the practice for the crash testing of safety hardware devices for use on the National Highway System (NHS)

- Federal Highway Administration (FHWA) has required that all new roadside safety hardware for which a Federal-aid reimbursement eligibility letter is sought be tested to MASH criteria*

*http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road.hardware/policy.memo/memo111215/
Develop a MASH Test Level-3 Short Radius System

- A short radius is a guardrail setup for intersecting roadways
- What do we need from a short radius
  - Containment
    - Vehicle capture and prevention of override or underride
  - Redirection
  - Deflection/Stoppage distance
  - Yet simple to construct
Short-Radius Project

Dissection of Short-Radius Functional Need

- **Anchor**: Need sufficient strength

- **Primary Roadway**: Need tensile and redirection capacities

- **Secondary Roadway or Driveway**: Need tensile capacity

- **Nose Section**: Need energy absorption

- **Area Behind the nose**: Need energy absorption

- **Bridge end**
Predictive Simulations of Crash Impacts Using HPRC: The Short Radius Example

Akram Abu-Odeh, Ph.D., Research Scientist
Roadside Safety & Physical Security Division, Texas A&M Transportation Institute

Short-Radius Project
Short-Radius – Previous Work

TTI-Thrie Beam System
Test 414424-2 (4400 lb pickup truck/62 mph/25 degrees)
(Failed to contain the test vehicle)
Short-RADIUS – Previous Work

Midwest Roadside Safety Facility

  - 4400 lb pickup truck (2000P)/61.5 mph/19 degrees (failed – vehicle penetration)
Finite Element Methodology

• Develop confidence in the model through
  • Material testing
  • Small component calibration
  • Full (previous) tests calibration
• Design safety device based on safety requirements defined in safety design manuals and based on previous research
• Multiple Simulation of concepts
• Choose best finite element model that represents the chosen design
• Run detailed finite element simulation to determine adequacy of new safety device for full-scale crash testing.
Finite Element Methodology

- LS-DYNA® from Livermore Software Technology Corporation (LSTC)
  - Explicit and Implicit dynamic time step integration
  - Library of highly nonlinear materials and robust contacts
  - Highly scalable on HPRC (MPP using Intel MPI protocol)
  - Available vehicle models and variety of pre- and post-processing software
- Explicit modeling of the railing components were included in the models
- Material models include elastic-plastic behavior
- Materials used are steel (different grades, sand, wood and plastic)
- Sand is modeled using smooth Particles Hydrodynamics (SPH)
- Bolts are explicitly modeled and pre-tensioned to provide the physical clamping among parts
Predictive Simulations of Crash Impacts Using HPRC: The Short Radius Example
Akram Abu-Odeh, Ph.D., Research Scientist
Roadside Safety & Physical Security Division, Texas A&M Transportation Institute

Short-Radius on Flat Terrain

Recommended Test Matrix

TL 3-31
TL 3-33
TL 3-35
TL 3-32
Truck TL 3-33: Flare and 700-lb Sand Barrels Spread Out

MASH 3-33 Truck Into Radius Nose (700 lb/barrel) Spread
Time = 0
Truck TL 3-33: Flare and 700-lb Sand Barrels Spread Out

Time = 0.095 seconds
Time = 0.295 seconds
Time = 0.545 seconds
Time = 0.695 seconds
Time = 1.045 seconds
Sand Barrel Impact on Stability

No Sand Barrels

With Sand Barrels
Recommended System Based on Simulation
Recommended System Details

Post and Barrel Spacing

Sandwich this Rail between nested Rails, as shown.

Detail A
Scale 1:10

Tangent to Parapet Face

3 sp. @ 37-1/2"
9'-4-1/2"

7 sp. @ 18-1/4"
10'-11-1/4"

3 sp. @ 75"
18'-9"

67-1/2"
56"

54"
30"

15'-6"
11'-6"

15'-0"
15-6"

15-6"
11'-6"

18-9"
3 sp. @ 75"

26"
20"

12-1/2"
50"
System Installation
(based on the design developed by simulation)
Truck TL 3-33: Predictive Simulation and Subsequent Crash Test
Conclusion
Simulations were conducted on TAMU HPRC machines EOS and ADA using 32 cores to 100 cores per job.

Wall clock time ranges from 26 hours to 56 hours depending on the size of the model and the simulation termination time (0.8 seconds to 1.7 seconds).

Domain decomposition is utilized for MPI scalability.

Special decomposition for sand (SPH) was used to spread the simulation effort along equally across the utilized cores (along with the Lagrangian parts).
Finite Element Methodology

- Vehicle with barrier model setup (showing all parts)
Finite Element Methodology

- Vehicle with barrier model (showing decomposition for 80-cores on ADA)
Conclusion

- Predictive simulations on HPRC was used to design and test five impact scenarios of high speed vehicular tests on roadway barrier.
- The barrier design for a short radius that has been elusive to achieve for many years.
- A 3TO1 ditch what excavated one foot behind the barrels edge for the last two tests.
- All these tests are considered pass according to MASH evaluation criteria.
Thank You!

Akram Abu-Odeh, Ph.D., Research Scientist
Roadside Safety & Physical Security Division
Texas A&M Transportation Institute
abu-odeh@tamu.edu
+1 979-862-3379