A Review of Available Vehicle Simulation Software

Dr. Roger L. McCarthy

May 19, 1998
Mission of the Automotive Research Center

“Creation of a flexible, agile simulation system”
Some Conference Objectives

- “Demonstrate dual use/dual need vehicle modeling and simulation tools”
- “Report on the latest advances in modeling and simulation of ground vehicles at various levels of detail”
Practical Simulation Requirements

- Must be substantially cheaper and faster to use than building prototypes
- Must model vehicle response accurately enough to make design decisions
- Must model vehicle response “at the limit” of vehicle performance
- Shouldn’t require a Ph.D. to use
Desired Simulation Output

- Lateral directional response (e.g., handling characteristics, yaw response, understeer/oversteer)
- Rollover propensity
- Steering dynamics (steering oscillation)
- Bounce and pitch (ride quality)
M38A1 Light Vehicle (the Jeep)
The M 151A2 Light Vehicle
HMMWV M998 (Humvee)
Publicly Available Vehicle Dynamics Simulation Codes

- Privately developed and for sale
- Publicly funded and more or less in public domain
General-Purpose Vehicle Dynamic Simulation Codes for Sale

- **ADAMS**
  - “Automatic Dynamic Analysis of Mechanical Systems”
  - Mechanical Dynamics, Inc., Ann Arbor, MI

- **DADS**
  - “Dynamic Analysis and Design System”
  - CADSI, Inc., Coralville, IA
ADAMS

- Has “virtual prototyping” software for vehicles, now used by “every major auto manufacturer, every single one”
- Has elements for suspension design, vehicle dynamics, engine design, powertrain engineering, body hardware engineering, NVH and ride
- Tire-roadway interaction
- Driver module
- Controls design, safety systems, motor sports, road surface wear, vehicle durability
ADAMS Limitations

- Expensive code for individual researchers
- Despite templates, a huge amount of vehicle-specific data must be entered for a simulation
- No publicly available benchmark of its accuracy and robustness
- Unless a large program is contemplated, cheaper to instrument and test a vehicle
DADS

- Has vehicle templates but less specialized than ADAMS, i.e., more customization required for each vehicle
- Has a tire module supporting "Standard Tyre Interface"
- Has a tracked vehicle module
- No public benchmarking, of which I am aware, of the vehicle modules
The National Highway Traffic Safety Administration (NHTSA) has funded the development of several vehicle simulation codes:

- FOROL, Dynamic Research, Inc.
- IMIRS, “Intermediate Maneuver Induced Rollover Simulation,” University of Missouri
- ADVS, “Advanced Dynamic Vehicle Simulation,” University of Missouri
Specialized Vehicle Dynamics Codes

- **LVDS**
  - “Light Vehicle Dynamics Simulation”
  - Vehicle Dynamics International, Norcross, GA

- **ADVS**
  - “Advanced Dynamic Vehicle Simulation”
  - University of Missouri-Columbia

- **VDANL**
  - “Vehicle Dynamics Analysis, Non-Linear”
  - Systems Technology, Inc., Hawthorne, CA
Analysis of Specialized Simulation Codes
Analysis of Simulation Results

- Evaluation of formulation and execution of code
- Comparison of simulation results with actual vehicle performance
  - Speed and steering wheel input data from a field test are applied to the simulation program
  - Result is compared with the vehicle’s actual performance during the test
Exponent Failure Analysis Associates (FaAAA) Test & Engineering Center

- Vehicle performance
- Restraint evaluation
- Explosive testing
- Aircraft seatbelt analysis
LVDS
Some Limitations of LVDS

- No steering model
- Fundamentally incapable of correctly predicting whether rollover will take place
  - Simplistic 2-D rollover model coupled to 2-D handling model
  - No pitch degree-of-freedom
  - Incorrect motions generated when multi-axial vehicle rotations occur
Comparison of LVDS Simulation of Avoidance Maneuver with FaAA Field Test
ADVS
Limitations of ADVS

- Piecewise-linear steering input
- Steering compliance not included
- Tire dynamics not modeled
- Shock absorbers located at spring positions, leading to substantial errors in roll damping
Limitations of ADVS

- Suspension camber compliance not modeled
- Errors in terrain code can result in erroneous tire forces
- No drivetrain model: vehicle speed profile cannot be specified directly
Limitations of ADVS

“[C]rash avoidance research typically is aimed at studying passenger vehicle response to driver handwheel inputs. ADVS, with no steering system, cannot be used for this.”

Evaluation of NHTSA Light Vehicle Handling Simulations, Chrstos and Heydinger, NHTSA, 1992
ADVS Validation Summary

- Not validated for limit maneuvers
- Not validated for inclined surfaces
- Roll angle over-predicted
- Steering and braking “adjusted” to produce correct path
- LVDS and ADVS results differ
Comparison of ADVS Simulation of Extreme Avoidance Maneuver with FaAA Field Test
VDANL
Limitations of VDANL

- Like LVDS, fundamentally incapable of correctly predicting whether rollover will take place
  - Roll motion simulation an add-on feature
  - Physically incompatible motions generated when large vehicle rotations occur
- Spring and damper forces improperly calculated for pitch motion
Limitations of VDANL

- Terrain model not a full three-dimensional surface
- Numerous errors and omissions in computer code
VDANL Steering Geometry
VDANL Simulation of Reversal Steer Maneuver at 10 MPH
VDANL Simulation of Reversal Steer Maneuver at 10 M PH (Top View)
Comparison of VDANL Simulation of Avoidance Maneuver with FaAA Field Test
Conclusions
Generic Limitations

- Tire modeling, esp. in limit maneuvers
  - Data generally lacking for extreme conditions
- Suspension parameters in limit maneuvers are VERY non-linear
- Soil models are very unsophisticated
- Excessive number of parameters
  - Many difficult to measure
- Compliance of joints, bushings, etc.
  - Difficult to measure; not static
- Sensitivity of output to small input changes
Conclusions: General

- Accurate modeling of limit maneuvers is desperately needed, but will require:
  - improved tire-roadway interaction models
  - incorporation of tire and suspension data for extreme conditions
  - improved terrain models

- Validation is critical
Thank You