Vehicle functional design – from PSA in-house software to AMESim standard library with increased modularity

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Vehicle Dynamics Expo 2009 – Germany – June, 17\textsuperscript{nd}
Agenda

1. From PSA in-house software to AMESim standard solution
2. Analysis, Porting and Validation of PSA models
3. AMESim: Open platform & modular approach for vehicle design
4. Conclusions
From PSA in-house software to AMESim standard solution

- 10 years of knowledge and capitalization at PSA using AMESim in house application
- PSA wishes a standard software solution, sharing capability with suppliers and potentially with other OEMs
- A software dedicated to functional design of the vehicle

**Main improvements versus in house code:**
- Overall C code optimization for real time capability
- Higher mechanical fidelity for Multibody dynamics (accelerations & gyroscopic effects, kinematics, Lagrange multiplier)
- Bushing compliance formulations and modularity
- Tire kinematics, formulations and modularity
- Sources for individual elementary tests
- Sensor models
- Data Import / Export (FDV)
- Misc: aero, jacking effect, viscoelastic models …
Vehicle Dynamics Modeling with a component approach and several complexity level for each component: AMESim Philosophy
Vehicle Dynamics : AMESim use at PSA

Vehicle Dynamics Reference tool

- Ride and Handling simulation:
  - Road inputs sensibility
  - Wind sensitivity / Aerodynamics
  - Stability (Lane change, Braking in curves, …)
  - Comfort (low frequency analysis)

- For:
  - Vehicle Dynamics Global Synthesis
  - Specification / Validation (Masses, Axle, …)
  - Competitor analysis

- During:
  - Car Development Projects
  - Preliminary Projects
  - Research Project / Pilot Studies

Reference models examples

- Full vehicle:
  - Global Analysis (all open-loop / closed loop maneuvers)
  - Sensitivity to lateral wind

- Kinematics & Compliance test bench « K & C »

- Flat-Track test bench

- Comfort test bench
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Analysis and Porting PSA Synthesis models

Global Analysis & Wind Sensitivity
- Full vehicle modeling (including Multibody chassis model with 15 DOF, compliance, modular tire models, advanced suspension modeling).
- Open / closed loop for longitudinal and/or lateral driver inputs
- Sensors models facility (control loop & post processing)
- All Sources can be provided with AMESim Standard signal library
- Open to model extension with other Imagine.Lab AMESim libraries (part and component elements – Hydraulic, Electric, Powertrain,…):

Flat Track – tire test bench
- Tire modular modeling (kinematics, belt, slip, stiffness):
  - linear / non linear / viscoelastic vertical stiffness
  - Relaxation length and scale factor even with Pacejka 92 formulae
  - Van Der Jagt effect for car park maneuvers
- External solicitations :
  - Lateral force (closed loop) or side slip (open loop)
  - Longitudinal force (closed loop) or longi. slip (open loop)
  - Vertical force
  - Camber angle
  - Steering angle / steering velocity
  - Adherence (constant, variable)
- Sensors models facility (control loop & post processing)
Analysis and Porting PSA Synthesis models

**Comfort test bench**

- Advanced suspension modeling for comfort (damper masses, viscoelastic models for bushings, dry friction model with stick/slip phenomena, suspension ratio, non-linear stiffnesses and damping law)
- Using tire modularity with excitation sources (All Sources can be provided with AMESim Standard signal library)
- Sensors models facility
- Frequency analysis capabilities with standard transferometer models (response of non-linear mechanical systems)

**Kinematics & Compliance bench**

- Carbody Fixed to the ground
- Functional modeling for excitation jack
- Controlled loop for suspension stroke
- Excitation Jack fixed to the spindle, allowing input forces at
  - Wheel Center
  - Base of wheel
  - Base of wheel with offset, taking into account the caster offset effect
- Input forces in all usual frame (Galilean, carbody, spindle,...)
- Sensors models facility
- All Source can be provided with AMESim Standard signal library
Validation example of PSA Synthesis models

Validation scheme

- Validation scheme
  - Validation on 3 maneuvers:
    - Steady state cornering (measurement at 0.3 g and 0.7 g)
    - Step steer 0.5 g
    - Step steer 0.8 g
  - Measurement variables:
    - Steady state cornering: Tire motor (F_x, F_y, F_z, M_z), Z_cog, Yaw & Roll velocity, steering rack position, Force on steering rack.
    - Step steer: yaw and roll velocity overshoots (max value and phase)

- Referential definition (starting point):
  - Initial model with all PSA modeling assumption reproduced.
  - Definition of a model architecture where both modeling (former in-house code and new VD implementation) lead “exactly” to the same results (differences less than 0.05% on all observed variables)
  - In this reference case, 60 operating points are evaluated

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Validation example of PSA Synthesis models

Modeling improvements
Quantification of the differences

Example # 1: Multibody model

Modeling Improvements:
- Accelerations & Gyroscopic effects
- Axle Kinematics formulation
- Interpolation algorithm

Only this improvement is considered here

Steady state cornering

<table>
<thead>
<tr>
<th>Steady state cornering</th>
<th>3D model</th>
<th>2D model</th>
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<tr>
<td>Fy (N)</td>
<td>2.257%</td>
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<tr>
<td>Fx (N)</td>
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Neglected at 0.3g
Impact at 0.7g (average of 1%, i.e. 20N on tire Fy and 10 on Fx steering)

Step steer 0.5 G

No significant impact

Step steer 0.8 G

No significant impact

Example # 2: Tire kinematics

Modeling Improvements:
- Side slip computation
- Long. slip computation
- Tire motor formulation at wheel center

Only this improvement is considered here

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Impact on roll velocity overshoot : 4%

Impact on yaw velocity overshoot : 1% and phase shift : 0.01 sec
Validation example of PSA Synthesis models

Example # 3 : Axle Compliance
Including previous modifications

Modeling Improvements:
- Lagrangian multiplier formulation
- Bushing modeling

Steady state cornering

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Impact at 0.7g (average of 4% on tire Forces, 4% on rack position, 7% on steering force)

Global impact on transients: roll velocity overshoot (mainly due to tire kinematics) and yaw velocity overshoot (mainly due to compliance)

Global impact on phase shift

Example # 4 : All modifications
Coupling all the effects

Modeling Improvements:
- Chassis (Multibody, Compliances)
- Tire formulation (kinematics, coupling effects, motor formulation at wheel center)
- Aerodynamics
- Suspension
- Overall Interpolation algorithms / methods

Steady state cornering

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Global impact on phase shift
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Modularity: Increasing complexity for suspension

Suspension Modeling

Modeling the damper subsystem technology

Functional Modeling of the suspension for comfort analysis (including Dry Friction and Viscoelastic models)

Advanced suspension interface for jacking effect

Simple suspension modeling

- Modularity for suspension modeling…
- … from very simple to complex approach, according to analysis:
  - Ride and handling, vehicle stability
  - Comfort
  - Damper analysis, design and optimization
Modularity: Sensors & Simplified vehicle models

**Sensors category**

- Current mechanical quantities
- Current OEM trade quantities
- All quantities available for post-processing and/or control loop

**Traffic detection / ACC**

- Using sensor facility and simplified models for traffic and vehicle detection

**Simplified Chassis models**

- Yaw plane model
- Several Yaw plane models with roll motion

- Connection for Subsystem design (Power Steering, …)
- Traffic modeling
- Vehicle dynamics understanding
- Educational
Modularity: Ready for Fuel Efficiency Analysis

- **Powertrain: Series & Parallel Hybrid architecture**
  - Connection with chassis to analyze the control strategies (tip in and back out in curves, slip μ, interaction with the ESP system...)
  - All electric motor types available for real time.
Modularity: Powertrain related features

Powertrain: Drivability

- Modeling Complex interaction between 3D engine block, carbody and driveline: vehicle comfort, engine harmonic filtering, Drivability
- All engine block topology available

- Torque Vectoring: Wheel torque management, piloted differential and all wheel drive
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| 4  | Conclusions                                           |
Conclusions

- PSA wishes to share a standard software solution with its suppliers and potentially other OEMs
- PSA reference frame for simulation has been improved
- High fidelity models, Robustness, CPU time reduction, Real time capabilities, links with optimization and PSA internal data management
- A unique platform for a system approach in Vehicle Dynamics:
  - **System view**: Chassis, Steering, Suspension and Transmission modeling with all AMESim libraries
  - **Process integration**: functional specification & design and functional validation
- Open **platform** with **modular approach** for vehicle design
- … from simple functional to advanced & detailed modeling for subsystems
Thank you!

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