Multibody Models: From Driving Simulator to On-Track Support

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“Our aim is to Design and Produce the fastest and safest race cars in the World”
Dallara Core Competencies

1. Design using composite carbon fiber
2. Aerodynamics
3. Vehicle Dynamics
4. Prototype Production

Style (Concept/Regulation)
Dallara ‘Commercial’ Racing Cars
Racing Car from Development to Racing 1

• Long Time Ago (Good Ol’ Days)

Basic Design

Limited Setup Tools

Very Limited Data to Analyze
Racing Car from Development to Racing 2

- Increasing Complexity

Highly Detailed Design

Huge Adjustability & Complex Characterization

Very Large Amount of Data
Increasing Complexity & Tight Competition

• Increasingly Tight Competition
Why Simulations

• Incorporating the whole car info in an unique simulation environment (MultiBody – Multi Physics), capable of virtually predicting car behaviour.
Why Simulations 2

- The Simulation Model connects to other blocks to extend its realism and accuracy.
Why Simulations 3

• The Simulation Model incorporates all the car information, connects the car Subsystems and is able to closely predict car behaviour.

Huge Amount and Availability of VIRTUAL Data

• Validation
• Correlation
Simulation Limits for On Track Activity

- The Simulation model is often used in its full complexity at home and in a ‘simplified version’ on track
  - From MultiBody – MultiPhysics to QuasiStatic, LookUpTable, Conceptuals...

- Duplication,
- Redundancy,
- Simplification,
- Not Coherence,
- Accuracy
Improving On Track Simulations

What I need on track?

- Same model, same data set of information, same behavior...

What can I accept to simplify on track?

- The analysis complexity, in order to have quick response time.

- Detailed Aero description,
- Detailed Mech description,
- Roll Experiment,
- Longitudinal Acceleration,
- Constant Speed,
- Cornering Equilibrium.
MultiBody/Physic Model in a Custom SW

Dallara Customized Software “LMPDos”
Software Capabilities

Full MultiBody Model with the detailed description of the car and its complete adjustability.
Software Capabilities

- Administrator or User log,
- Capability to generate & compare set-up sheet, same format same files than those used to initialize a Driving Simulator Run or an off line complete car SIM.
Simulations – Aero Interpolation

The model has the whole aerodynamic description in term of options & aero maps.
Simulations – Target Speed Experiment

@ Selected top speed, No longitudinal acceleration
Simulations – Top Speed Experiment

From the aero/powertrain data and the track input geometry
Simulations – Roll Experiment

Depending on the selected Mechanical & Elastic setup and Aero “pre-load”
Simulations – Cornering Experiment

Reproduce a “steady state” mid corner equilibrium of the multi-body model.

Possibility to select a corner of a track (curvature, bank angle... already in database)
Cornering Experiment - Details

Replicating mid corner steady state conditions:

\[ \dot{u} = \dot{v} = \dot{r} = 0 \]

Initialization (phase 1):
Model starts in straight line configuration, with an initial speed lower than the target.

Pure Cornering (phase 2):
Steering wheel controller acts in order to reach target radius at initial speed, checking the theashold of OS/US

Steering Pad (phase 3):
Once @ target radius a throttle controller acts in order to slowly reach the targets speed (very low longitudinal acceleration). A lateral controller acts at the same time to maintain the curvature radius.
Cornering Experiment - Details

**Input**
- Aero & Mech Setup
- Target speed
- Curvature
- Bank
- Grade
- Grip

**Output**
- Body angles: roll, pitch
- Suspension configuration: steer angle, bumpstop engagement, toe, camber, ride heights, damper length
- Dynamics indices: understeer gradient, lateral acceleration
In Summary

With a “customized” software we are able to export and keep update the multibody model for our customers. This is the same model used for off-line and driving simulator sessions, both for customers or car development.

This software is able to reproduce simple test cases for “on track” activities reducing the need of user manuals, look up tables and quasi static simplified model. Allowing a more refined virtual work before real testing.
Future Development

- Having just one model running in a central server the customer can access via Cloud (easy to keep controlled and updated and faster computational timing),
- Increasing the capability of the multibody model to be “predictive” off line for example in speed profile, accelerations...
Thank you for your attention