Dirt Late Model Racing Simulations in Dymola / Modelica

Nate Horn

nate.horn@claytex.com
Dirt Late Model Racing Simulations

• Claytex Background

• VeSyMA Suite (Vehicle Systems Modelling and Analysis)

• My Background

• Dirt Late Model Racing

• The Simulations

• The Challenges
Who are Claytex?

• Users of Dymola and Modelica since 1999

• Dymola distributors since 2003 (Dassault Systemes partner since 2008)

• Major customers include Automotive OEM’s, suppliers and Motorsport teams (Formula 1, NASCAR, Indycar)
  – First Formula 1 customer in 2004, currently support half the grid
  – First worked with Dallara in 2008 for IndyCar
  – First NASCAR customer in 2009, currently support all the manufacturers and top teams
  – Active in a number of other series
  – Supporting Motorsport inspired academic research programs

• rFpro system integrator since 2009
  – High fidelity graphics, audio and track models
  – Claytex offer complete tool chain to run the vehicle model
  – Support ADAS and autonomous vehicle development by feeding data to sensor models
VeSyMA Suite

• Suite of Modelica libraries for Vehicle Systems Modelling and Analysis

• First available in Dymola 2018

• Core platform enables performance, fuel economy and energy analysis
  – Drive cycle simulation

• Application specific extensions provide detailed models across many areas
  – Engines, powertrain, vehicle dynamics, driver-in-the-loop

• Open and extendible to easily connect libraries from other developers
  – Electrified Powertrain and Battery libraries from Dassault Systemes
  – Thermal Systems library from TLK Thermo
My Background

• University of Iowa (B.S. and M.S.) in Mechanical Engineering

• Boeing Commercial Airplanes for 2 years

• Worked at Red Bull for 5 years until the operation shut down in 2011
  – Opportunity to collaborate with the Red Bull F1 team
  – First NASCAR team to use Dymola / Modelica
  – Introduced to Mike Dempsey (Owner of Claytex)

• Worked for 5 years at Chip Ganassi Racing (NASCAR program)
  – Vehicle Dynamics Group Leader
    • Simulation
    • Software
    • 7 Post Testing
  – Performance Group Manager
    • Add Aerodynamics

• Started at Claytex in February of 2017
  – Start up the US office
• Started down this path to build a simulation package to use for demonstration purposes
  – Nobody in Motorsport want to share anything
  – I have background in this type of racing / simulation

• It also provided an opportunity for me to ‘use’ the VeSyMA suite as if I were a customer
  – Highlight areas for improvement
  – Feed these things into the Claytex ticketing system to be added / improved

• Push development forward in new areas
• Top prize payouts
  – as high as $1,000,000 (once)
  – down to $800 for local weekly racing events
  – ‘big’ races generally referred to as anything $5k or higher to win

• The Series
  – World of Outlaws
  – Lucas Oil Series
  – UMP
  – MARS
  – Corn Belt Clash
  – MLRA
DLM Racing

- Vehicle 2350 lbs (1066 kg)
- Engine/Transmission
  - Naturally Aspirated - Carbureted
  - V8 - 2 valves / cyl - Pushrod - Roller Cam
  - 420-440 cu inch (7.0-7.2L)
  - 900 HP (670 kW)
  - 9600 Peak RPM
  - 2 speed direct drive gearbox
- Front Suspension
  - Dual A-frame
  - Coil over
  - Rack and pinion steering
- Rear Suspension
  - Solid Axle “quick change”
  - 4 bar linkage on each side
  - Panhard bar
  - Torque reaction via lift arm
- Tires / Wheels
  - 15 inch diameter wheels
  - 14 inches wide
  - Multiple tire compounds legal (depending on series)
  - Tread patterns are ‘cut’ by team (depending on series)
  - Pressure 6-12 psi (40-80 kPa)
- Differential
  - Spool (locked LR to RR)
DLM Racing

- West Liberty
  - ½ mile in length
  - 5 degree banking
  - Wide corners
  - Wide racing surface

- Our ‘home’ track in college

- Fast laptime during qualifying: 18.73 seconds

- Winner slow laptime in feature: 22 seconds

- Over 3 seconds of laptime falloff is common
The Simulations - Same Vehicle Model

- Started with the VeSyMA - NASCAR vehicle
  - VehicleInterfaces Library standard
  - Swapped to Rack and Pinion steering
  - Built custom rear suspension model
  - Started with a VeSyMA aero model and customized
    - Estimated the aerodynamic model inputs based on limited information
    - Created a custom setup event (starting from NASCAR example)

- Added STL of a Body for visual reference
The Simulations - Same Vehicle Model

- **‘MassCheck’**
- **‘Body Fixed KnC’**
- **‘Swept Sine 7P’**
• Representative workflow for a racing application
The Simulations - Kinematics Assembly

- Algebraic model to assemble components
  - Inputs in local part coordinates
  - Outputs in vehicle coordinates
The Simulations - Setup Event

- Closed loop adjustment simulation
  - Adjusts camber shims (camber angles)
  - Adjusts tierod lengths (toe angles)
  - Adjusts body CG x and y position (front and Is weight %)
  - Adjusts spring preloads (ride height and cross weight)
  - Adjusts ARB droplink length (ARB preload)
The Simulations - Mass Check

• Simple simulation to check the results of a Setup sim
  – If adjustments are properly applied to car it will remain static for the entire sim... if there are errors in transferring data across the car will oscillate
  – In this example, the car oscillates and settles with different wheel loads... indicating there is an issue
The Simulations - Pulldown Rig

- Pulldown rig (‘pushup rig’)
  - General low frequency analysis
  - Wheel rates
  - Roll rates
  - Camber gain
  - Damper to wheel motion ratios
The Simulations - 7 Post Swept Sine

- Modal analysis on a 7 post rig
  - Extract Body modes
    - Heave
    - Pitch
    - Roll
    - Other?
- Tire vertical load variation
  - Optimize Damping
The Simulations - Quasi Static

- Single State target... divided up into 5 steps
  - Note that the upper ‘four bar’ load is approaching zero at this point on the track
The Challenges

• Input data…
  – Reasonable spring and damper input data
  – Questionable accuracy on vehicle geometry
  – Questionable aerodynamic data
  – Questionable tire models
  – Questionable track geometry
The Challenges

- Validation data is even more scarce
  - Geometric data
  - Low frequency data (Pulldown / K&C)
  - Higher frequency data (7P)
  - On-track data

- Alternative methods
  - iPhone logging of acceleration data has proven useful
  - GoPro video is often enlightening

- “Bad data is worse than no data”
  - I would argue that some insight is better than no insight

** Credit: Damian Harty’s 2017 NAMC Keynote Presentation
The Challenges - Validation Data

- West Liberty
  - ½ mile in length
  - 5 degree banking
  - Wide corners
  - Wide racing groove

- Fast time during qualifying: 18.73 seconds
- Winner slow lap in feature: 22 seconds

- 3 second falloff over the course of an event is common.
The Challenges - Validation Data

• Logged data vs ‘accelerometer’ reading in the simulation model
• VeSyMA was used to construct a suite of dirt late model simulations with Dymola / Modelica

• This project demonstrates the power of Dymola / Modelica as well as the usefulness of VeSyMA

• An experienced Dymola user, utilizing VeSyMA can build a set of simulations like this efficiently

• Even though many assumptions were made, the resulting simulations were useful

• Are these simulations perfect? No.
• Are these simulations helpful? Absolutely.
Dirt Late Model Racing Simulations in Dymola / Modelica

Questions / Thoughts / Comments?

Nate Horn
nate.horn@claytex.com
+1 (704) 951-7461