Advanced Data Acquisition to Improve Vehicle Performance: An Argentinean Case Study

Stefan Kloppenborg
OptimumG

Overview

- Company Introduction
- The Testing Program
- Differential Behavior
- Slip Angle Measurements
- Motion Ratio Analysis

OptimumG Services

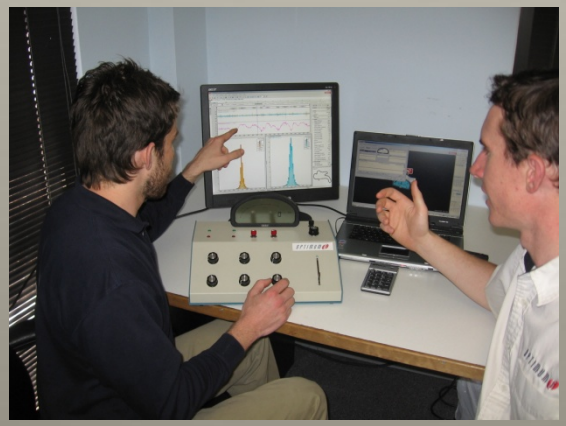
We specialize in vehicle dynamics and provide our clients with:

- Seminars & training
- Consulting services
- Simulation software development

Seminars & Training

We provide seminars based on our clients' needs:

- Public & In-House Seminars
- One-on-One Training
- 3, 4 & 12 day Seminars



Seminars & Training

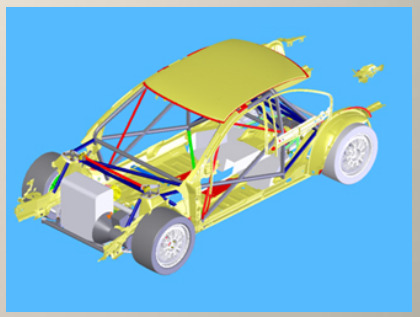
304 seminars . 13 years . 6,400 participants

Alcon
AP Brakes
Brembo
Bridgestone-Firestone USA
Bridgestone Technical Center Europe
BMW
Citroen Sport
Corrsys-Datron
Chrysler
Dunlop
Ferrari
Ford Advanced Vehicle Operations
Goodyear
Mac Laren
Magneti-Marelli
Michelin
Mitsubishi
Multimatic
MoTeC
Nascar
Ohlins
Penske
Pi Research
Pirelli
Porsche
PSA Peugeot Citroen
Toyota
ZF-Sachs

Consulting

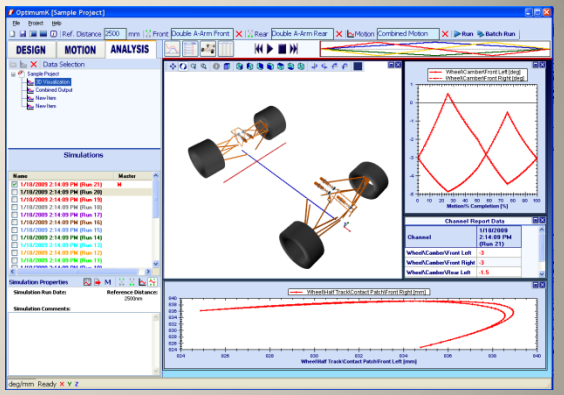
Chassis design

- Suspension design
- Vehicle concepts
- Testing & Development
- Aerodynamics studies
  - Model design
  - Wind Tunnel Testing

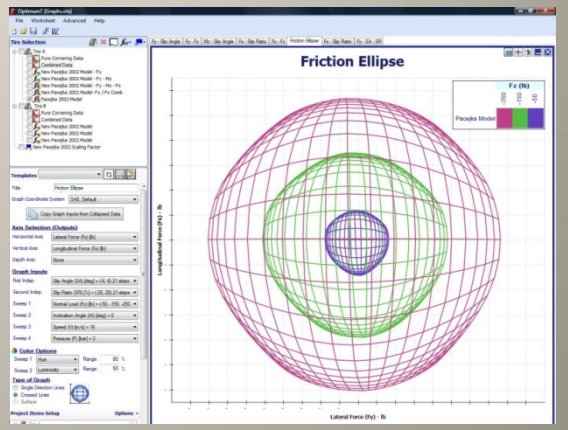


Software Development

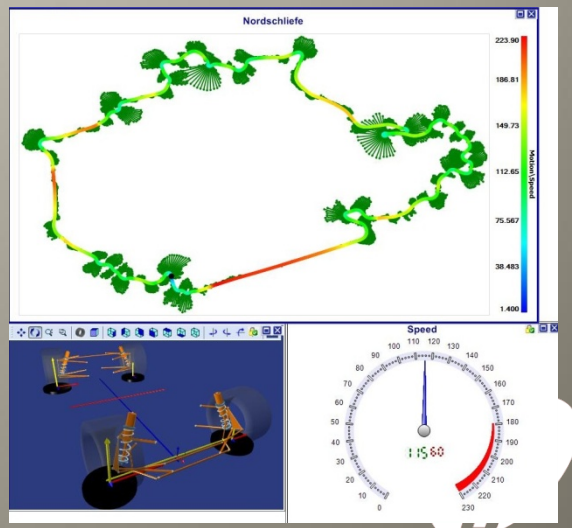
OptimumK kinematics software



OptimumT tire data visualization & modeling software



CVD steady state computational vehicle dynamics



Testing, February 2010

- Oreste Berta SA, Alta Gracia, Argentina
- 6 days of testing
- 9 tests

Testing: The Car

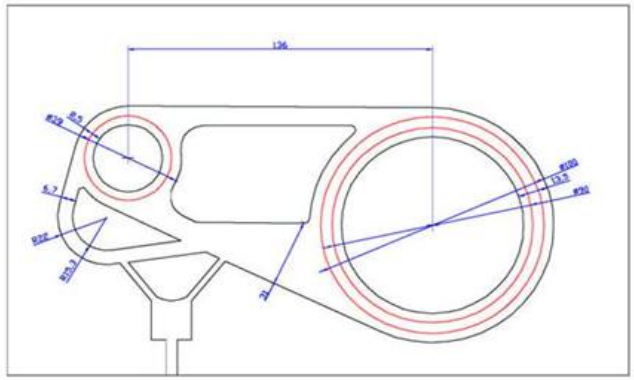
TC2000 Touring Car
- Front wheel drive
- 300+ HP 4 Cylinder
- Double wishbone front suspension
- Solid axle swing arm rear suspension

Testing: The Tests

- Constant speed skidpad (ISO 3888-1)
- Increasing speed skidpad (ISO 3888-1)
- Slalom
- Double lane change
- Straight line, constant speed
- Straight line coastdown
- Accelerating/braking
- Chassis dynamometer
- Laps of handling course

Testing: The Tracks

Berta Test Track

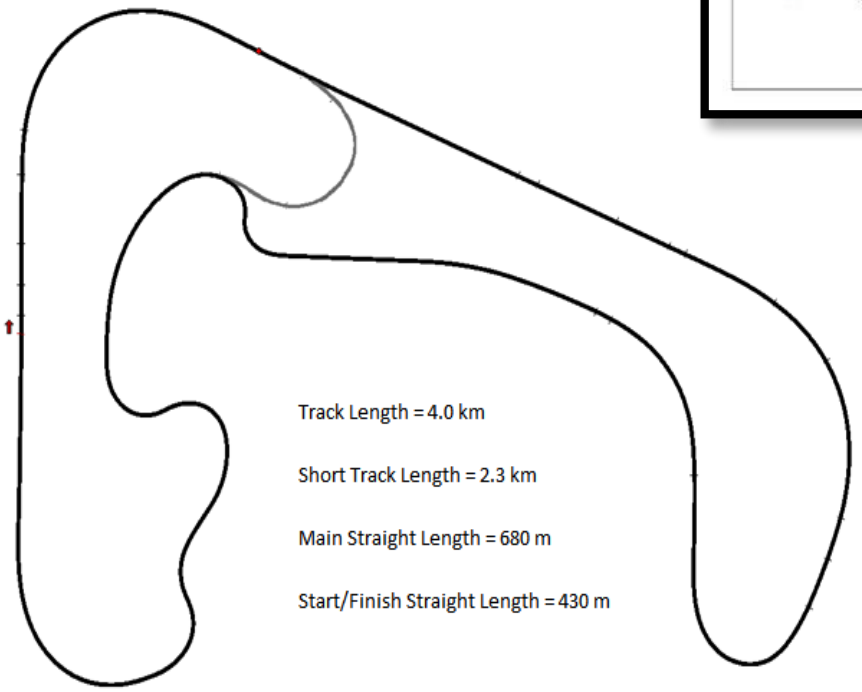


Track Length = 700 m

Straight Length = 135 m
Large Skidpad Outer Diameter = 110 m

Small Skidpad Outer Diameter = 50 m

Cabalen Road Course



Track Length = 4.0 km

Short Track Length = 2.3 km

Main Straight Length = 680 m

Start/Finish Straight Length = 430 m

Oreste Berta SA
Alta Gracia,
Argentina

The Partners

- Oreste Berta SA
  - Test track, vehicle preparation
- Kistler/Corrsys-Datron
  - Wheel force transducers, slip angle sensors, height sensors, measurement steering wheel, wheel vector
- MoTeC
  - Data acquisition hardware and software
- GeneSys
  - Inertial platform
- Texys
  - IR tire temperature sensors, pitot tube

Differential Analysis

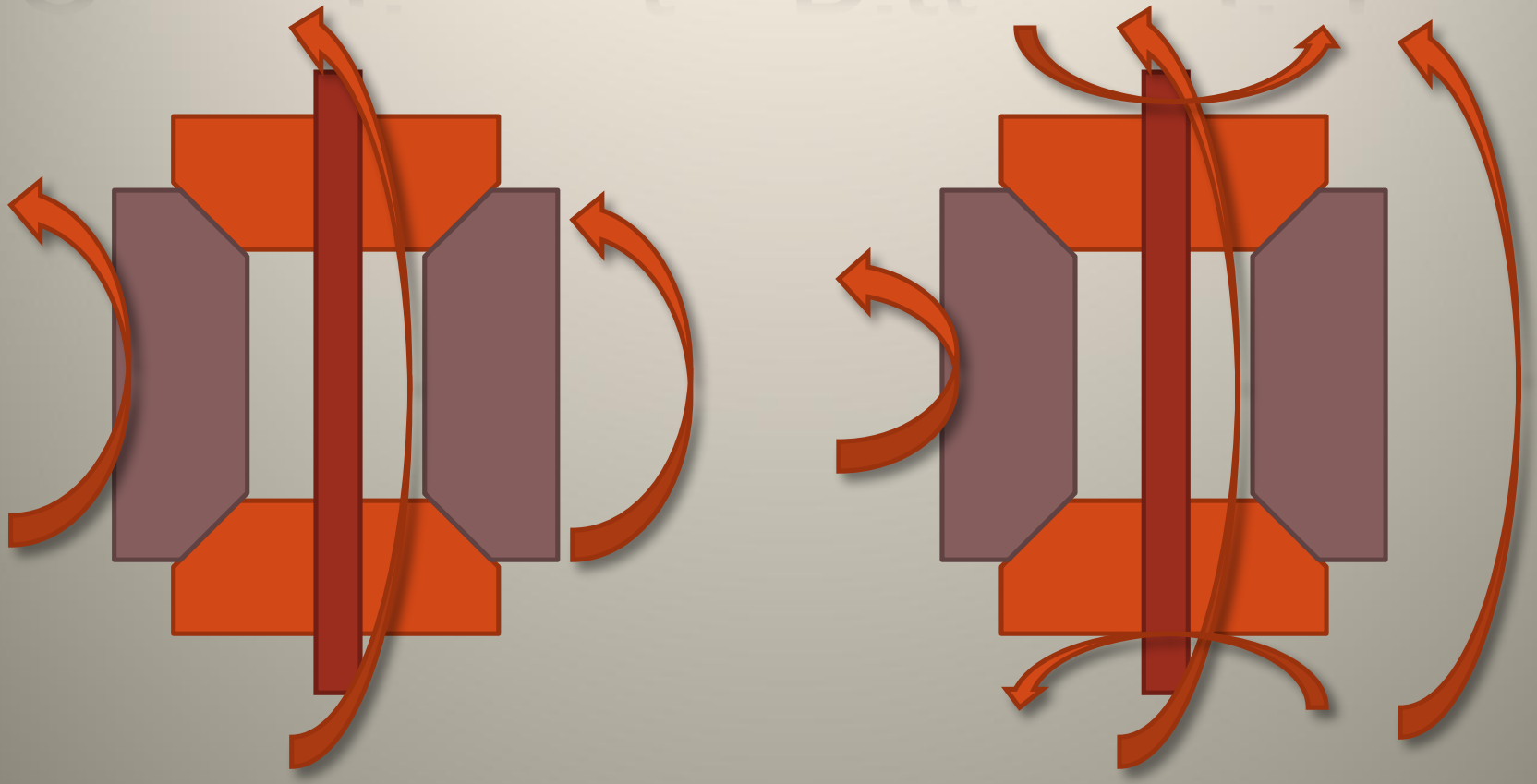
- The differential allows drive torque to be applied to both driven wheels

- The differential can have a large effect on the handling of the vehicle
  - Differences in left and right drive torque causes a yaw-moment

Differential Analysis

- The vehicle tested has a limited-slip differential
  - A clutch pack allows different torque to be applied to the left and the right wheel

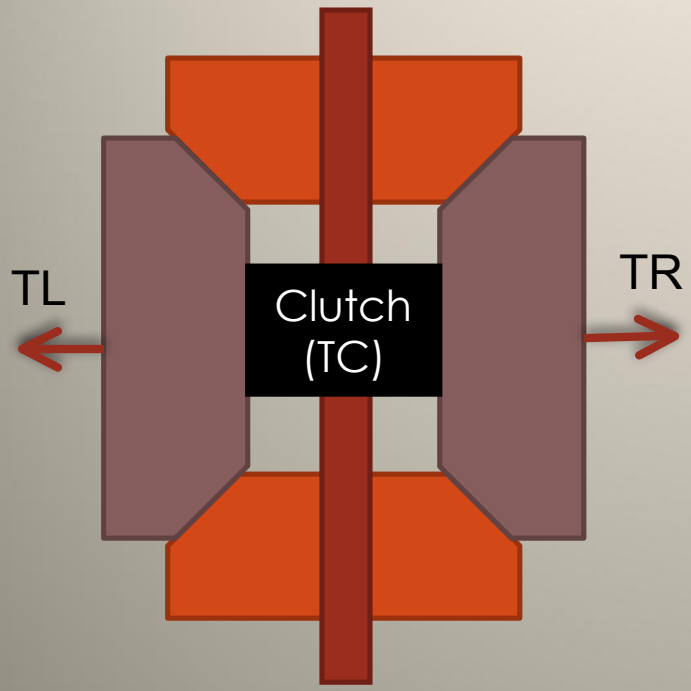
Operation of a Differential



Straight Ahead Driving

Turning

Limited Slip Differentials



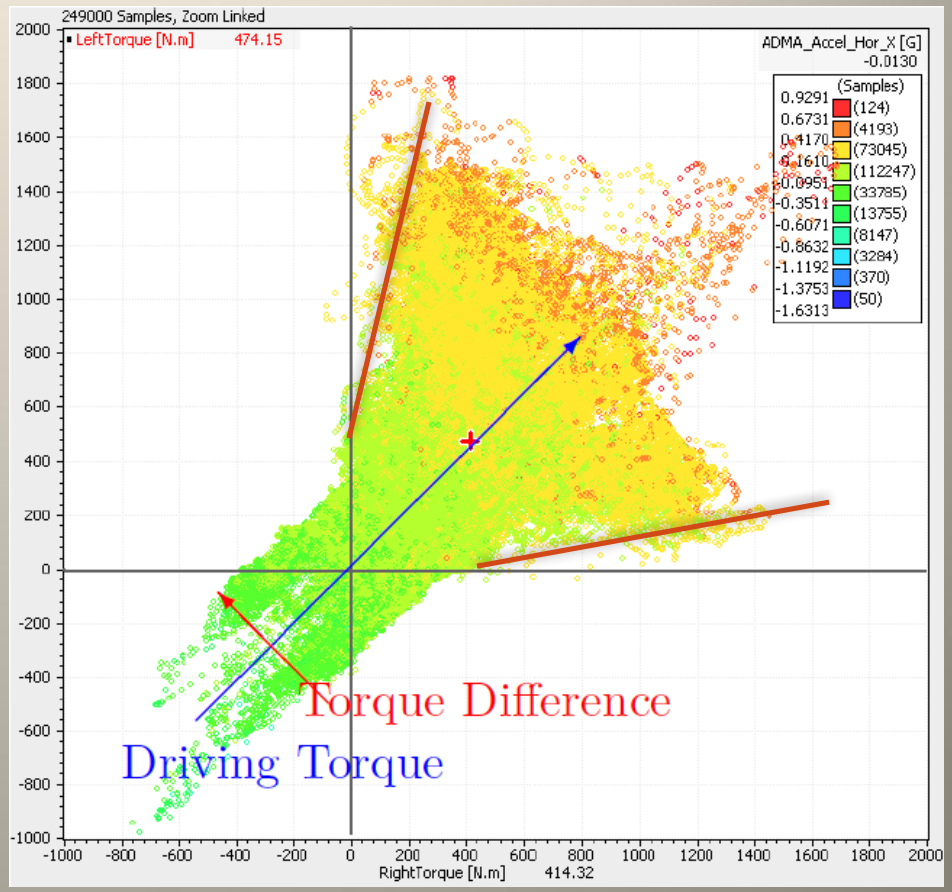
- When |TL-TR|<TC
  - –Left and right wheels are locked together
- When the differential is unlocked
  - |TL-TR|=TC

Differential Analysis: Sensors

- Kistler RoaDyn S625 wheel force transducer

Differential Analysis

- By plotting left drive torque versus right drive torque, we see the envelope of possible operating torques

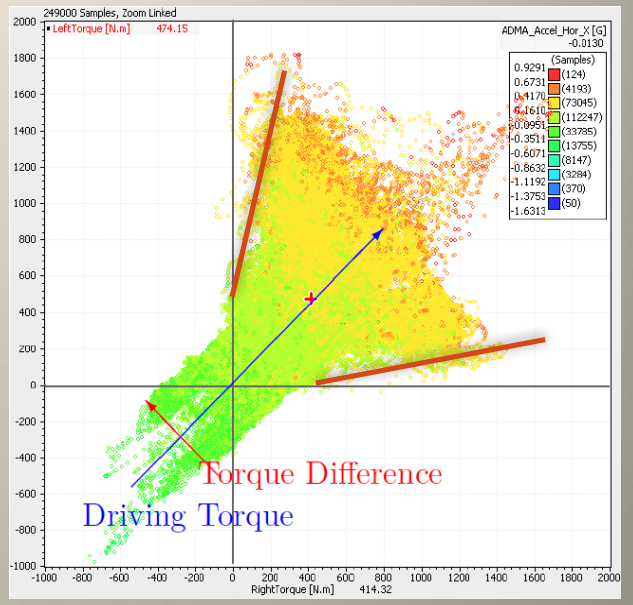


Differential Analysis

- We find that the boundary is described as:

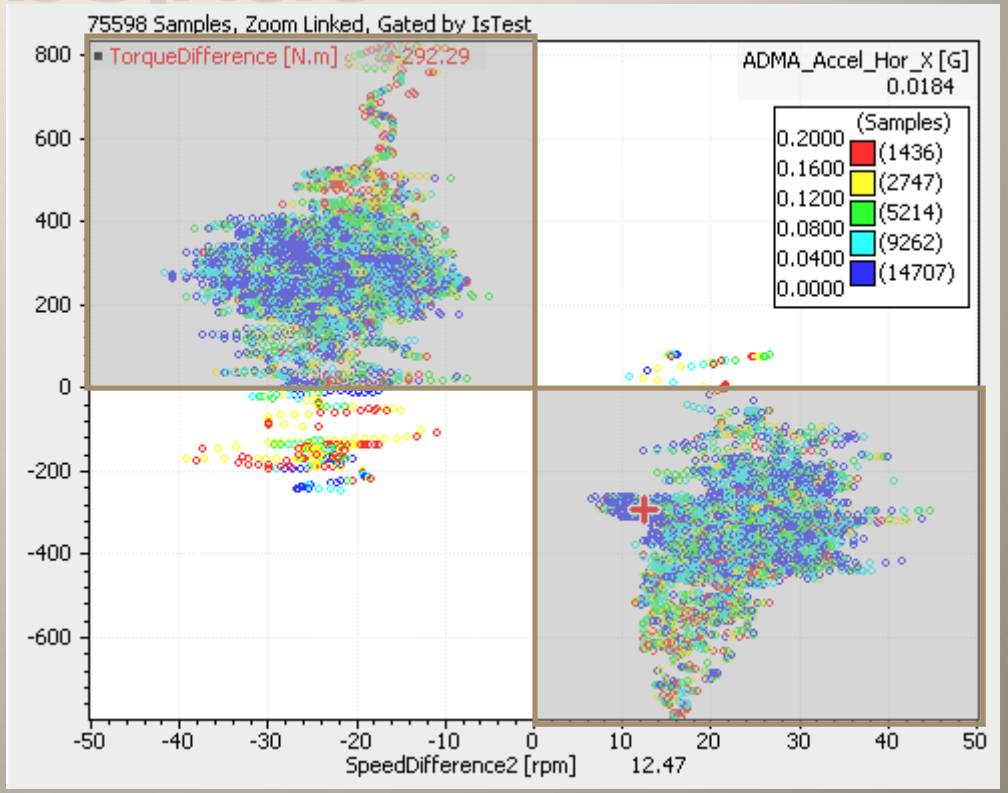
$$|TL-TR| < C\,(TL+TR) + B$$

C=0.55
B=250 Nm



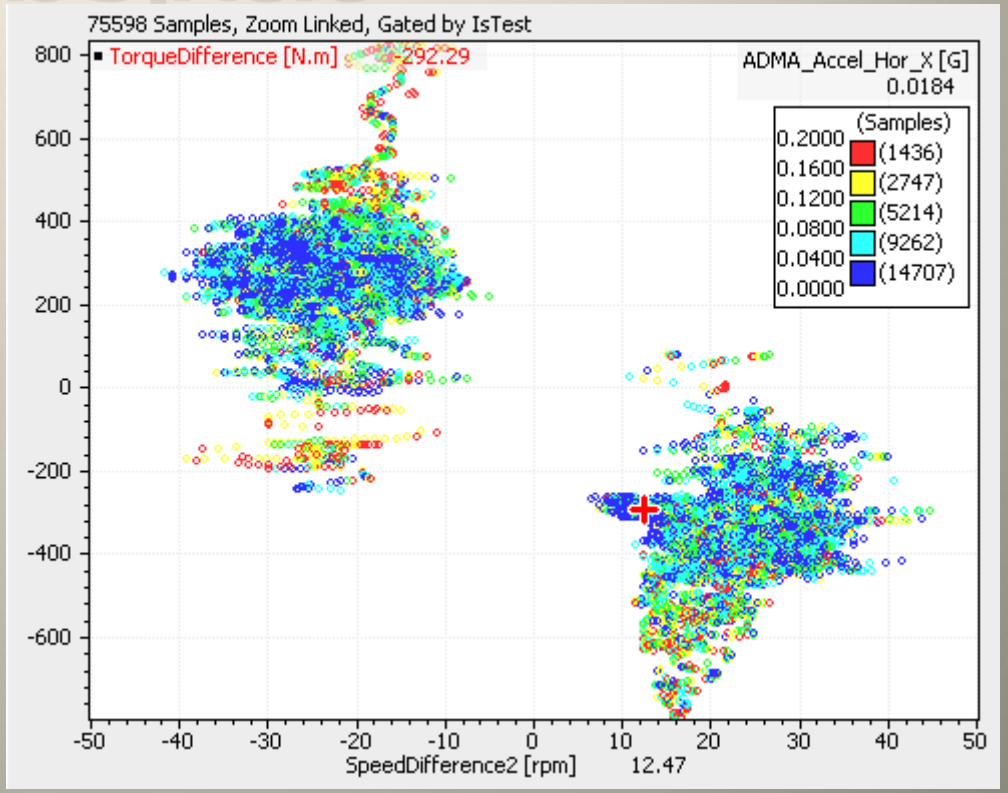
Differential Analysis

- We find that there is a relationship between the torque difference (TL-TR) and the speed difference



Differential Analysis

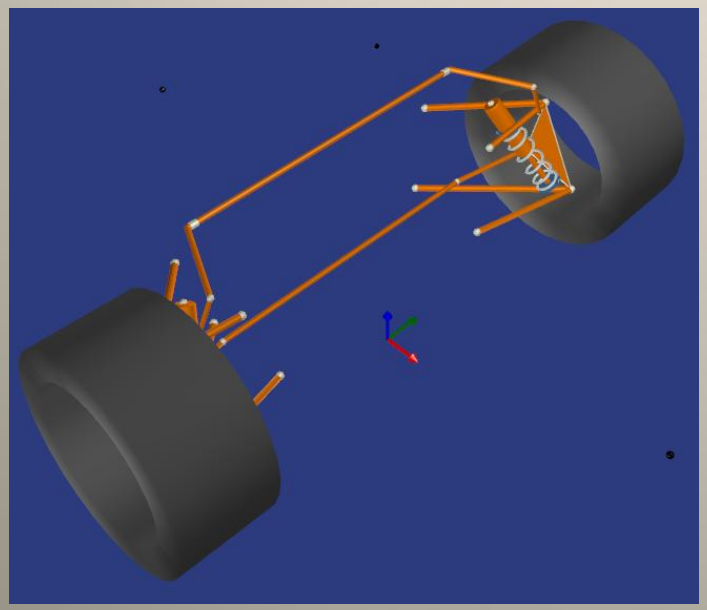
- The clutch uses friction, so can only transfer torque from the fast wheel to the slow wheel
  - Not the other way around!

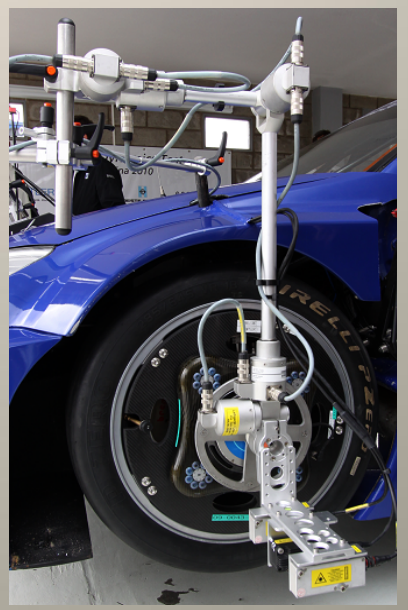


Suspension Kinematics Measurement

- Suspension kinematics are typically determined by:
  - Kinematics analysis
  - K&C Testing (in a lab)
- Can also be measured on a proving ground

Kinematics Comparison





Kinematics Measurement

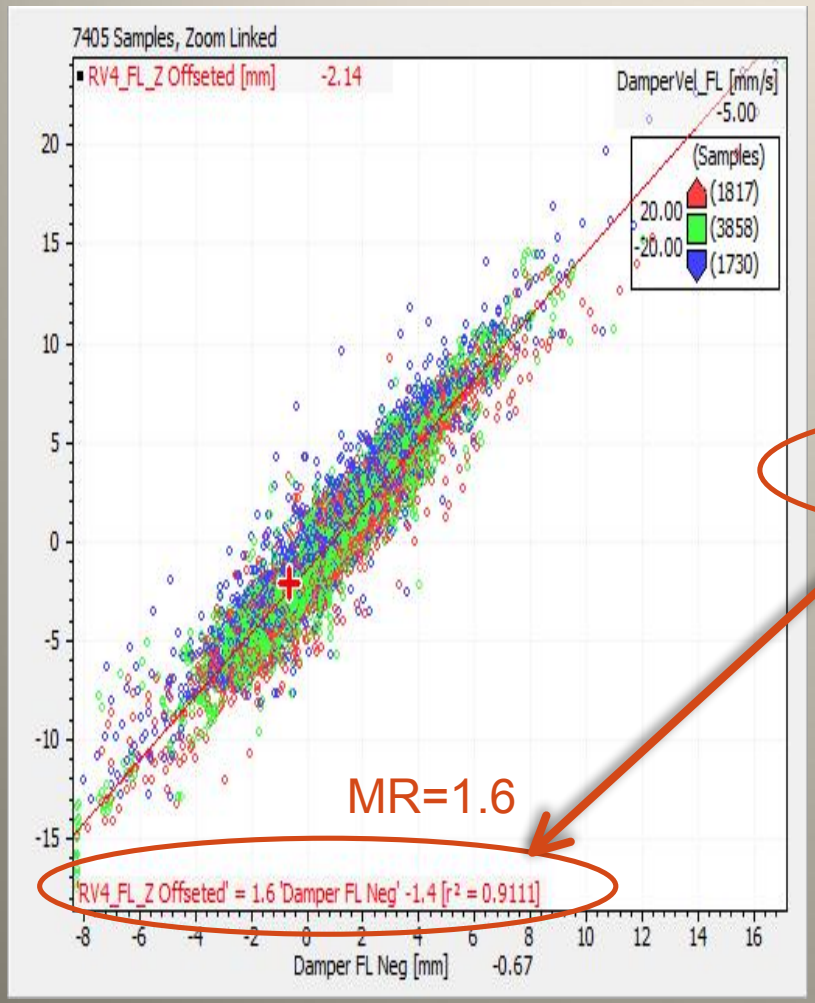
- Corrsys-Datron RV4
  - –X, Y, Z Position
  - –Steering angle
  - –Camber angle

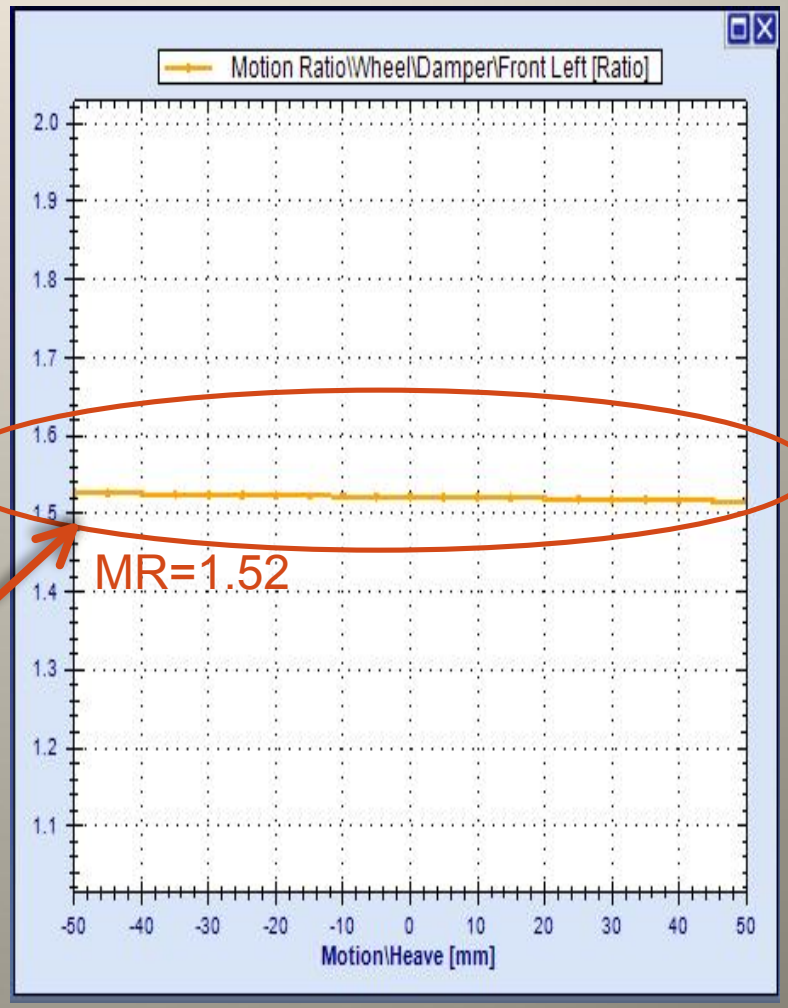
- Linear potentiometer
the damper

Motion Ratio Comparison

- Compare:
  - –Wheel movement measured with RV4
  - –Wheel movement calculated with damper movement and suspension kinematics software

Motion Ratio Comparison





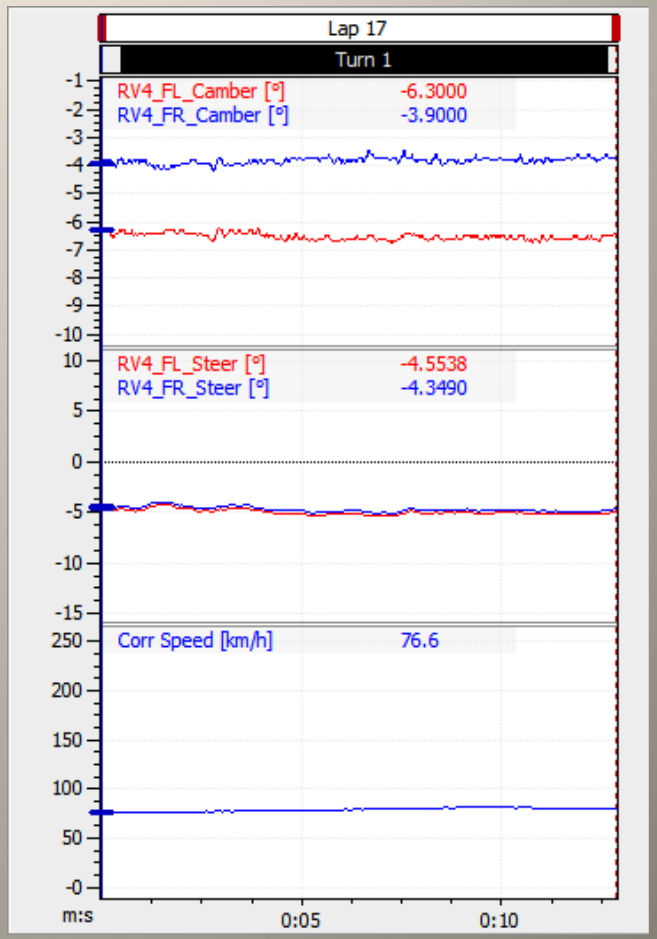
Motion Ratio Comparison

- The differences come from:
  - Compliance
  - Inaccuracies in the kinematics model

Kinematics Measurement

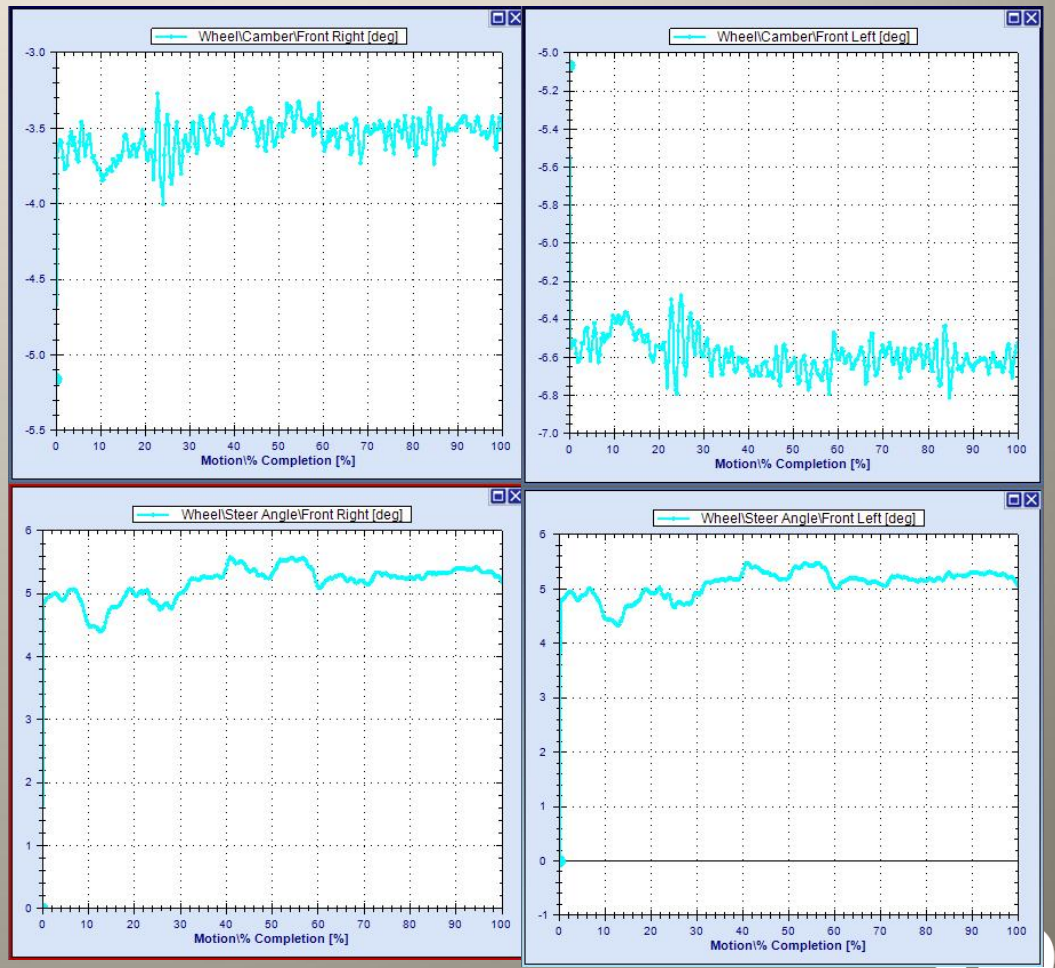
Data from a constant speed steady-state circular test, we see:

- Camber variation
- Steering variation (inside-outside)

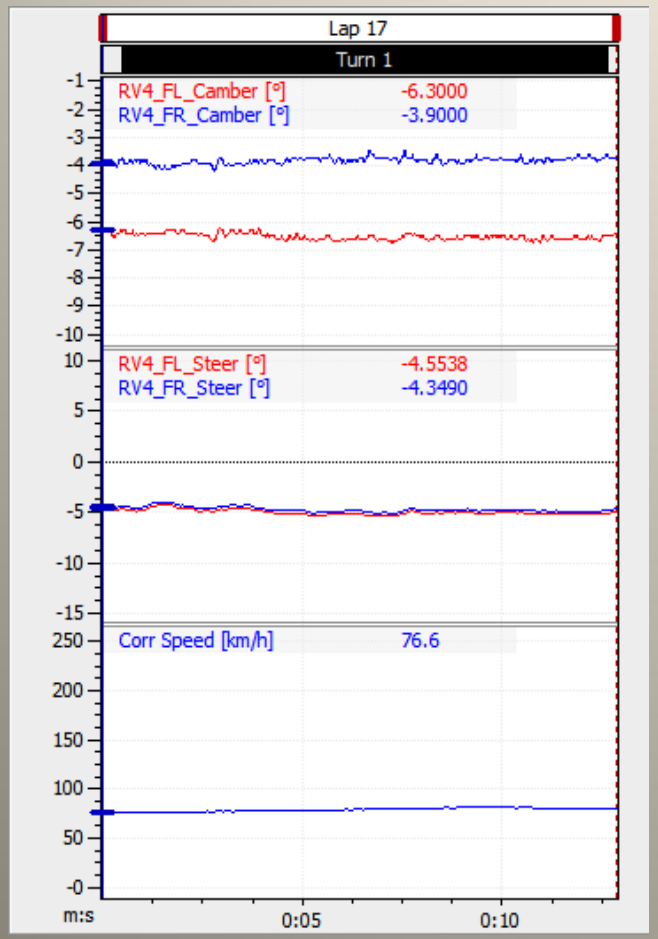


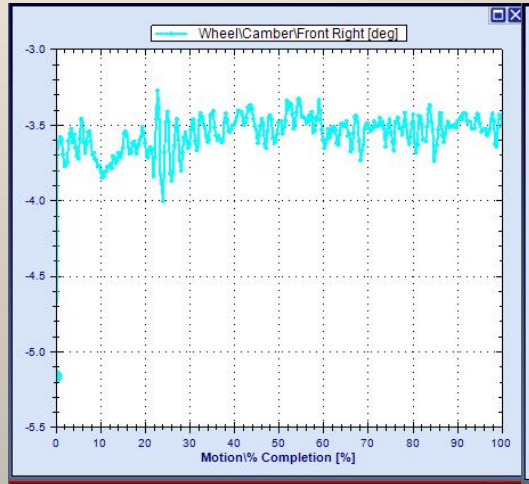
Kinematics Measurement

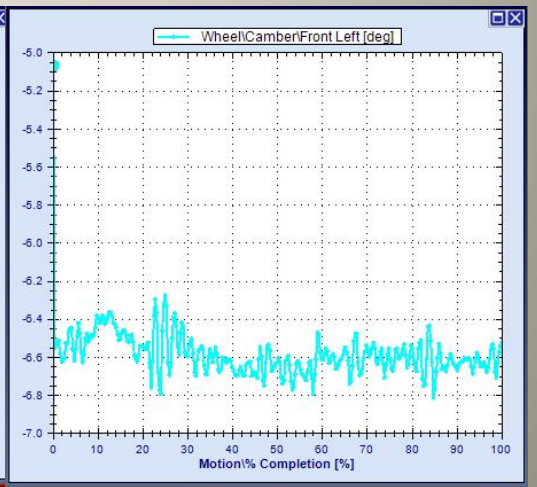
- Import steering and damper position into OptimumK

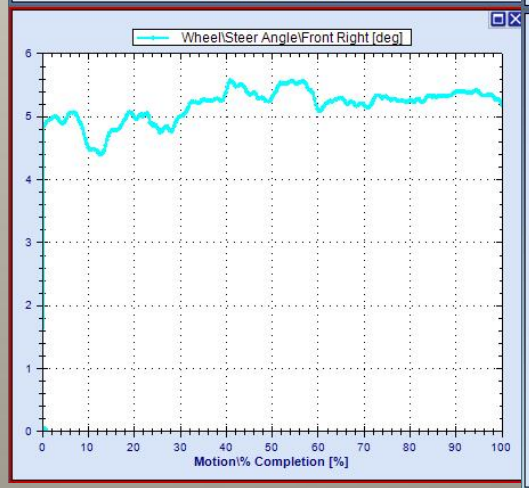


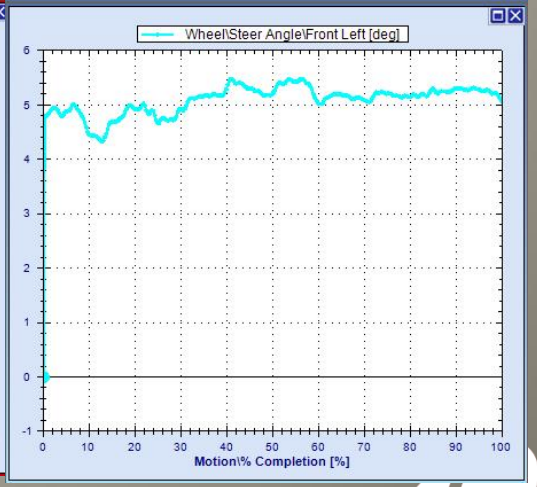
Kinematics Measurement











Kinematics Measurement

	Left Hand Turn				Right Hand Turn			
	camber		steer		camber		steer	
	FL	FR	FL	FR	FL	FR	FL	FR
Simulation	-3.5	-6.7	5.5	5.4	-6.6	-3.6	-5.1	-5.2
Measurement	-3.4	-6.4	4.6	5.3	-6.5	-3.8	-5.0	-4.7
Difference (%)	**2%**	**4%**	**20%**	**4%**	**1%**	**6%**	**2%**	**10%**

Errors in measurement of steering geometry

Thank You!

If you are interested in any further information about our company, services or software programs, don't hesitate to contact us.

OPTIMUM

8801 E. Hampden Avenue, Suite 210
Denver, Colorado 80231 USA
+1 303 752 1562
engineering@optimumg.com
www.optimumg.com