A new approach to steady-state and quasi-steady state vehicle handling analysis

Presentation
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Vehicle Dynamics Expo
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OptimumG - Overview

• Vehicle Dynamics & Data Acquisition Seminars
  – In-House Seminar
  – Public Seminar

• Consulting
  – Track Testing
  – Race Engineering
  – Data Acquisition
  – Mechanical Design
  – ...

• Software Development
  – OptimumK
  – Simulation
Vehicle Dynamics & Data Acquisition Seminars
- In-House Seminar
- Public Seminar
- One-on-One training
- From 1 to 12 days
- Design around customer needs
- 8900 Power Point Slides to choose from
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312 Seminars / 12 Years
Over 6000 Satisfied Customers

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- Magneti-Marelli,
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- Mitsubishi
- Multimatic
- MoTeC
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- Ohlins
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- Porsche
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- Toyota
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• Mechanical Studies

• Chassis Design

• Suspension Geometry Design
• Race Car Engineering
• On Track Engineering
• On Track Testing
• Lab Testing
• Data Acquisition
OptimumG – Software Development

- OptimumK: Kinematics software
OptimumG – Software Development

- OptimumT : Tire Data Fitting and Visualization Software
OptimumG – Software Development

- Computational Vehicle Dynamics
  - Steady State simulation
  - Quasi-Steady State simulation
  - Yaw Moment Diagram – Moment Method

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• About CVD

• CVD Presentation
  • Design
  • Motion
  • Setup
  • Analysis

• Quasi Steady State Simulation

• Pure Steady State Simulation

• Steering Simulation

• Yaw Moment Diagram Simulation

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• CVD (Computational Vehicle Dynamics) calculates the behavior of the car in *steady state*

• **Steady state**: all the forces and moments are balanced in each step of the simulation
  - No inertia
  - No damping

• Calculation of lateral and longitudinal grip
  - Reaction of both suspended and non suspended mass
  - Weight Transfer
  - Tire Deflection
  - ...

• However, CVD could consider the case where the yaw moment is not equal to zero allowing the user to analyze parameters like *understeer* or *oversteer*. 
Front Suspension Templates:
- Double A-Arm
- Nascar
- Mac Pherson
- Mac Pherson Pivot Arm

Rear Suspension Templates:
- Double A-Arm
- Mac Pherson
- Nascar
- V8 Supercar
- Five Link
Create as many Setup as you want

Setup split in 4:
- Masses and CG
- Others (Stiffness, Brake, Diff...)
- Tire Model
- Aero Maps

Fast Setup changes
**Masses and CG Inputs**

- Corners Masses
- Non Suspended Masses
- CG Total Height
- Non Suspended Masses CG

![Import - Export and Print icons](image)
Other Inputs

- Spring Stiffness
- Anti Roll Bar Stiffness (or Belleville Washers Stiffness)
- Brake Distribution
- Drivetrain Configuration
- Static Ride Height
- Non Suspended Mass CGs
- Chassis Torsional Stiffness
**Tire Model**

- Pacejka
- Fiala
- STI
- Harty

**Visualization Tools:**
- 2D Graph
- 3D Graph
- Tire Forces Calculator
Aero Maps

- Cz Front and Rear
- Cx
- Aero Balance
- Efficiency

• Aero Map Visualization:
  - 3D Graph
  - Iso Lines
• In CVD the inputs are based on forces and speed

• 3 types of motion can be generated according to the need of the user.
  – Pure Steady State
  – Quasi Steady State
  – Yaw Moment vs. Lateral Acceleration diagram
Pure Steady State (PSS)

PSS motion:
Yaw moment equal to zero → Steering wheel angle is calculated in order to maintain the equilibrium.

Skid Pad Simulation

Parameters

Yaw Moment = 0
Lateral Acceleration = Input
Steering Wheel Angle = Output
Body Slip Angle = Output
**Quasi Steady State (QSS)**

- QSS motion: the steering angle is an input and therefore the yaw moment is not zero anymore.

Forces, Roll and Pitch Moments are in equilibrium.

**Parameters**
- Yaw Moment = Output
- Lateral Acceleration = Input
- Steering Wheel Angle = Input
- Body Slip Angle = Output
**Yaw Moment Diagram**

- In a diagram motion the input is a sweep for both body SA and steering wheel angle. For each point the lateral acceleration and yaw moment are calculated and then a diagram can be generated. This gives a quick visualization of parameters such as control, stability, behavior at the limit.

**Parameters**

- Yaw Moment = Output
- Lateral Acceleration = Output
- Steering Wheel Angle = Input
- Body Slip Angle = Input
CVD – Analysis Tools

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• For a given speed an longitudinal acceleration, the **yaw moment diagram** covers the full maneuvering envelope and presents the results graphically in one graph.

• Graphic analyze of the stability and control of an automobile.

• Analogy with aeronautical techniques.

• Force/Moment study instead of motion study avoids filtering effects of the inertias and give the ability to isolate results of small changes in the vehicle configuration not discernible in a transient response.
Yaw Moment Diagram - Construction

Sweep of Steering Wheel Angle
Sweep of Body Slip Angle
Vehicle Speed
Longitudinal Acceleration
Vertical Acceleration

Iso Body Slip Angle
Iso Steer Angle
Yaw Moment Diagram – How to use it?

- Zero-body slip angle curve
- Stability
- Zero-steer curve
- Control
- Limit behavior
- Oversteer
- Understeer

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Stability

- **STABILITY**: The slope of the zero-steer curve shows the yaw moment (N) for different CG body slip angle (β). This is called the directional stability of the car.

- The magnitude tells you how much yaw moment is acting on the car with zero steering input. The sign is always the opposite sign as the lateral acceleration sign, thus this yaw moment tends to reduce the body slip angle.
**Control**

- **CONTROL:** The yaw moment generated at 1° of steering shows the derivative of yaw moment (N) with regard to steering angle. This is a measure of the yaw moment control that the driver has.

- Lateral acceleration generated at 1° of steering shows the derivative of lateral acceleration (Y) with regard to steering angle. This is a measure of the lateral-acceleration control that the driver has.
Limit Behavior

• **LIMIT BEHAVIOR:** If the tip of the diagram is above the line yaw moment (N) = 0 for positive lateral accelerations, then the car is limit oversteer (spin).

• If the tip of the diagram is below the yaw moment (N) = 0 for positive lateral accelerations, the car is limit understeer (plow).

• Note that a car can be limit oversteer but understeer in terms of trim behavior.
Yaw Moment Diagram – Overlay
Yaw Moment Diagram – Overlay (2)
Motion:
- Lateral Acceleration: ramp from 0 to 1 G
- Speed: 200 Km/h
- Steering angle: 0 to 60 Deg
Analysis – QSS Simulation (2)

Friction Ellipse

Roll in suspension and tires
Analysis – PSS Simulation

Motion:
- Same motion as QSS
- Calculating the steering wheel angle

Weight Transfer

Visualization of forces
Analysis – PSS Simulation (2)

Friction Ellipse

Roll in suspension and tires
Motion:
- Sweep of steering angle
- Analyze weight transfer due to steering geometry
Analysis – Yaw Moment Diagram

Motion: Sweep of the steering angle only to analyze the weight transfer due to the steering geometry

- More Oversteer and lateral acceleration and higher speed
- More corner entry understeer at lower speed
- Less control at 100 km/h but more stability.
Baseline Configuration, 100 Km/h and 150 km/h

- Understeer tendency at the limit for stiffer front suspension
- Same corner entry behavior
- Less control with stiffer springs in the front
Analysis – Yaw Moment Diagram (3)

Baseline Configuration, Stiff Spring in the front

- Understeer tendency at the limit for stiffer front suspension
- Same corner entry behavior
- Less control with stiffer springs in the front
"There is no such thing as understeer or oversteer: there is only under-yaw or over-yaw moment"