

Oversteer and Understeer Part 1

So far the work on vehicle behaviour in lateral acceleration has looked at the SAE definition of understeer, oversteer and neutral steer based on steering angles.

As a reminder, the SAE defines neutral steer as:

A vehicle is neutral steer at a given trim if the ratio of the steering wheel angle to the overall steering ratio (ie the actual steered wheel angle) equates to the Ackerman steering angle for a given radius of turn.

Ackerman steering angle δ (delta) is the geometric steered wheel angle required for a car of wheelbase L to track round a turn of radius R at low speeds where the external forces due to accelerations are negligible so $\delta = L / R$ for small angles.

Understeer and oversteer are then defined in similar ways as:

*A vehicle is **understeer** at a given trim if the ratio of the steering wheel angle to the overall steering ratio is greater than the Ackerman steering angle for a given radius of turn*

*A vehicle is **oversteer** at a given trim if the ratio of the steering wheel angle to the overall steering ratio is less than the Ackerman steering angle for a given radius of turn*

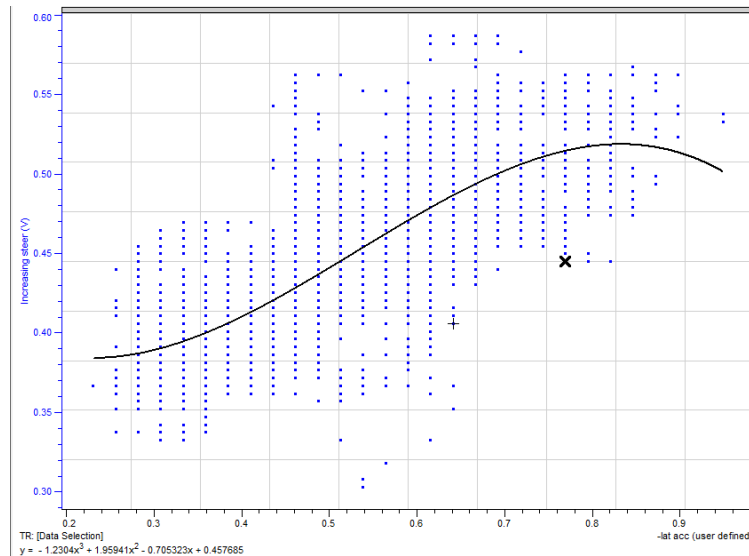
Another relatively simplistic definition of handling balance Blundell and Harty (2004) describes oversteer as being ‘*strictly the condition in which slip angle of the rear exceeds that of the front*’

The work then went on to look at load distribution and how the individual wheel loads will affect the lateral force generated and how the load split distribution front to rear can be used to predict the handling behaviour of a vehicle.

The basic assumption was made that if the front wheels have a greater load split than the rear the car will have less grip under limit cornering at that end and so ultimately the car will understeer. The same argument is used for oversteer but in this case the rear wheels have the limiting levels of grip. In this way the behaviour of the car should be predictable from a knowledge of the dynamic load distribution when cornering

This next section examines how the physical car actually behaves when cornering and demonstrates ways this can be measured to demonstrate the levels of understeer or oversteer actually occurring.

The easiest way to show this for a car in steady state cornering is to plot steering angle against lateral acceleration. The steering effects can be visualised by the following graph. This shows a plot of lateral acceleration against steering volts. On this graph 0 v represents the Ackermann steering angle for the cornering car on the SMU steering pad. It can be seen that as lateral acceleration increases so does the steering volts. From the SAE definition therefore anything over 0V will be understeer.



The **understeer gradient** is the gradient of the curve of lateral acceleration vs steer angle. It is useful in refining the description of vehicle's handling behaviour. An understeering car that has a positive understeer gradient will exhibit greater understeer as lateral acceleration increases and will consequently feel more understeering. An oversteering car will see a steering angle less than ackerman. A car may feel as though it is oversteering as the gradient becomes negative as the driver has to back off the steering as the turn progresses even though the steer angle is still greater than the ackerman steer angle - but it is still understeering.

Introduction to Transient Behaviour

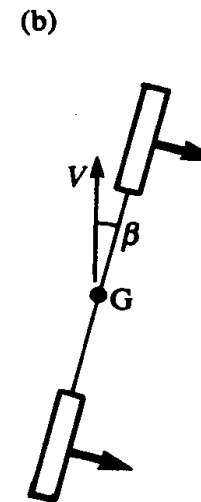
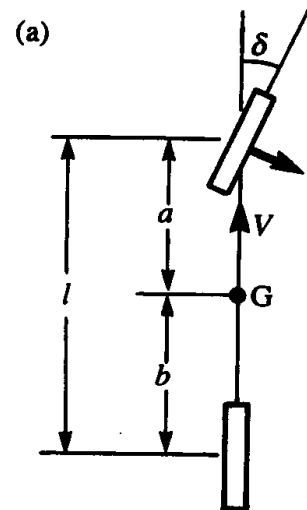
To look at the next refinement of the concept of understeer and oversteer and consider the behaviour of the car as it enters a corner we need to look at the simplistic 'Bicycle Model' and then apply them to a 4 wheel vehicle.

Steady State Vehicle Behaviour described with the Bicycle Model

- This technique, is widely used to demonstrate the behaviour of the vehicle in the ground plane
- The 'bicycle' model was originally defined by Segal (1956)
- More accurately referred to as having 2 degrees of freedom (2 DOF) **lateral velocity** and **yawing velocity**.
- The approach is described in many texts on the subject including Bastow et al (2004), Dixon (1996), Gillespie (1992) and Milliken and Milliken (1995).

Dixon (1996 p337) describes the bicycle model which has the following features:

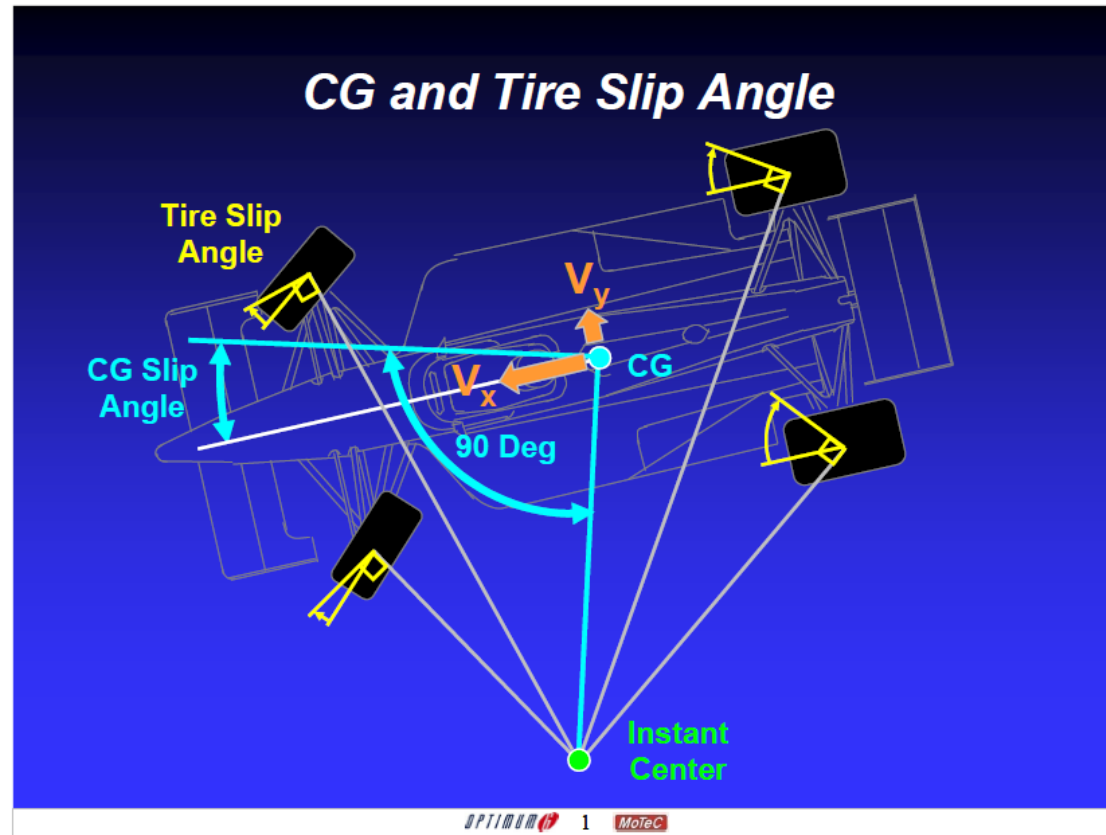
- The model has no suspension, aerodynamic forces and tractive forces and uses small steer angles and the handling is deduced in a particularly simple way, from the front and rear tyre side force coefficient versus slip characteristics.
- Load transfers both lateral and diagonal, camber, are omitted. This model reduces the behaviour of the two wheels on each axle to a single wheel as a way of simplifying the analysis at this introductory stage.
- This method could be described as a kinematic approach because, although forces are considered, the result is to relate the response in kinematic terms to the control inputs.
- The analysis assumes that there is a linear relationship between steer angle and lateral acceleration - so called linear theory. The path curvature, yaw speed and lateral acceleration are produced as a function of the inputs of steer angle and forward speed. These variables can be determined by practical tyre testing.



- The bicycle model shows two non-equilibrium conditions of the vehicle. a) steer and no yaw and b) yaw and no steer.
- In a) there is a steer angle (δ) but no vehicle yaw, the result being a lateral force and moment produced by the front wheel.

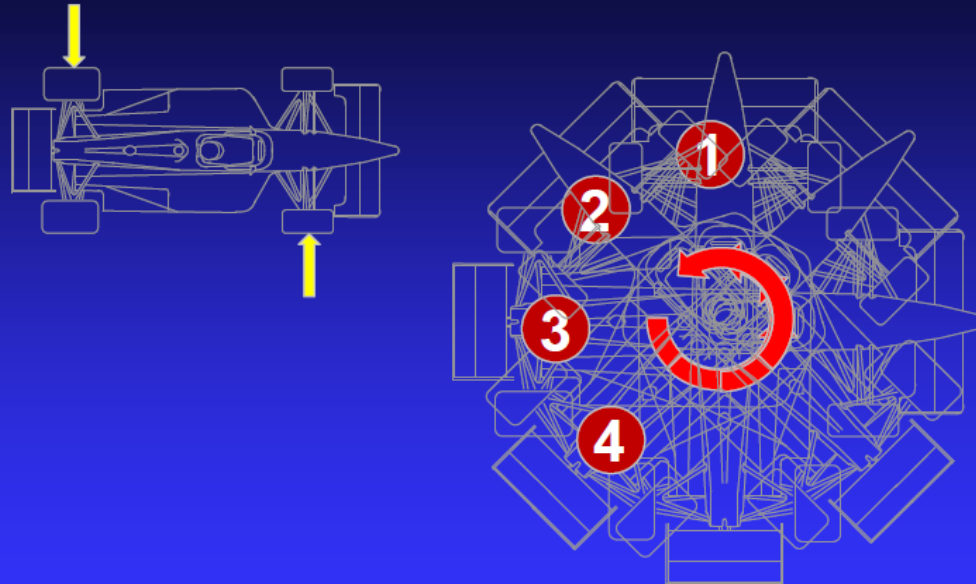
- *In b) there is a vehicle yaw angle (β) with no steer angle. Again, there is a lateral force and a moment. In this case, the total force acts close to the centre of mass, usually a little behind it. Thus the moment from yaw can be balanced by a steering moment from a relatively small steering angle.*
- *An alternative way to view this is that the yaw angle gives a rear wheel slip angle and the steering can be used to give a suitable front slip angle to give zero yaw moment and hence constant yaw speed i.e. steady state. Thus, handling depends on a balance between front and rear yaw moments.*

To develop this simple concept into a four wheel vehicle and demonstrate what would be meant in real terms the slides from the Optimum G course by Claude Rouelle can be used. In this case the term vehicle slip angle is used in place of the vehicle yaw angle as the vehicle is assumed to be travelling forward.



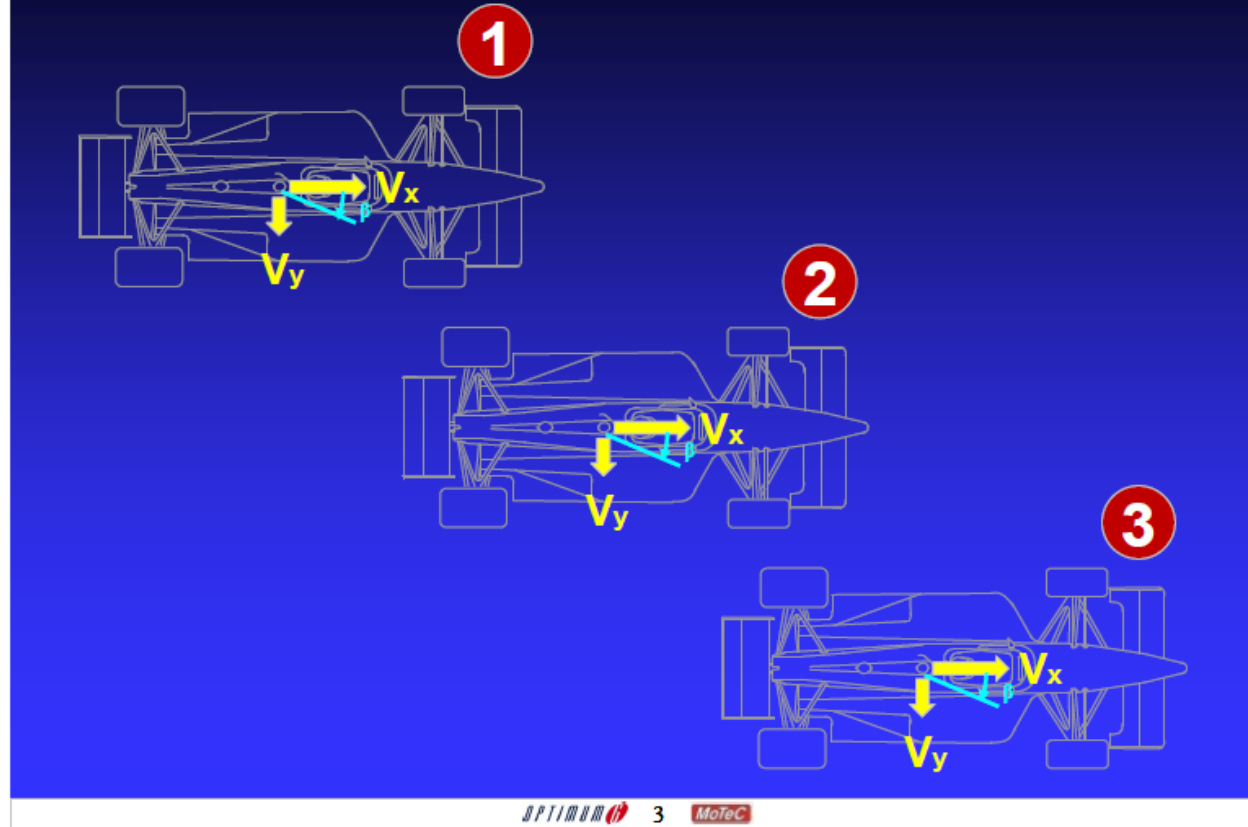
Basic Definitions of 4 wheel vehicle in cornering

Yaw Rate But No Slip Angle

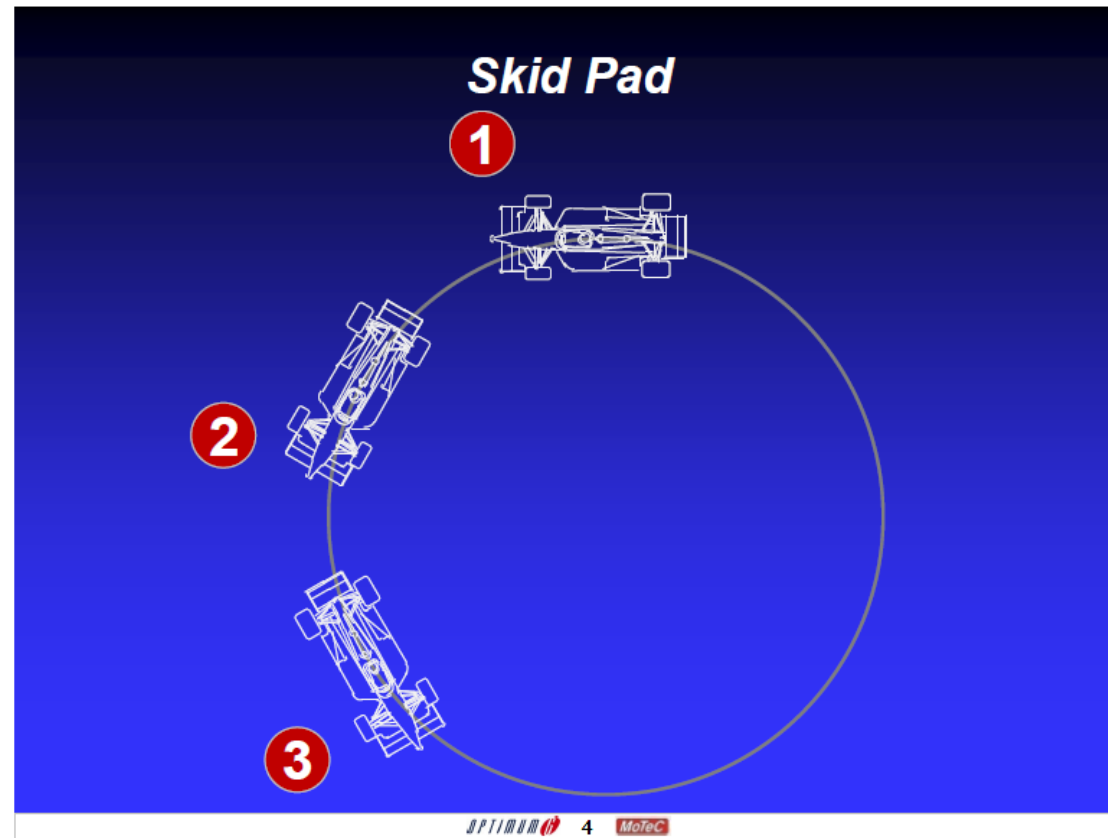


Example of a car rotating but making no forward progress

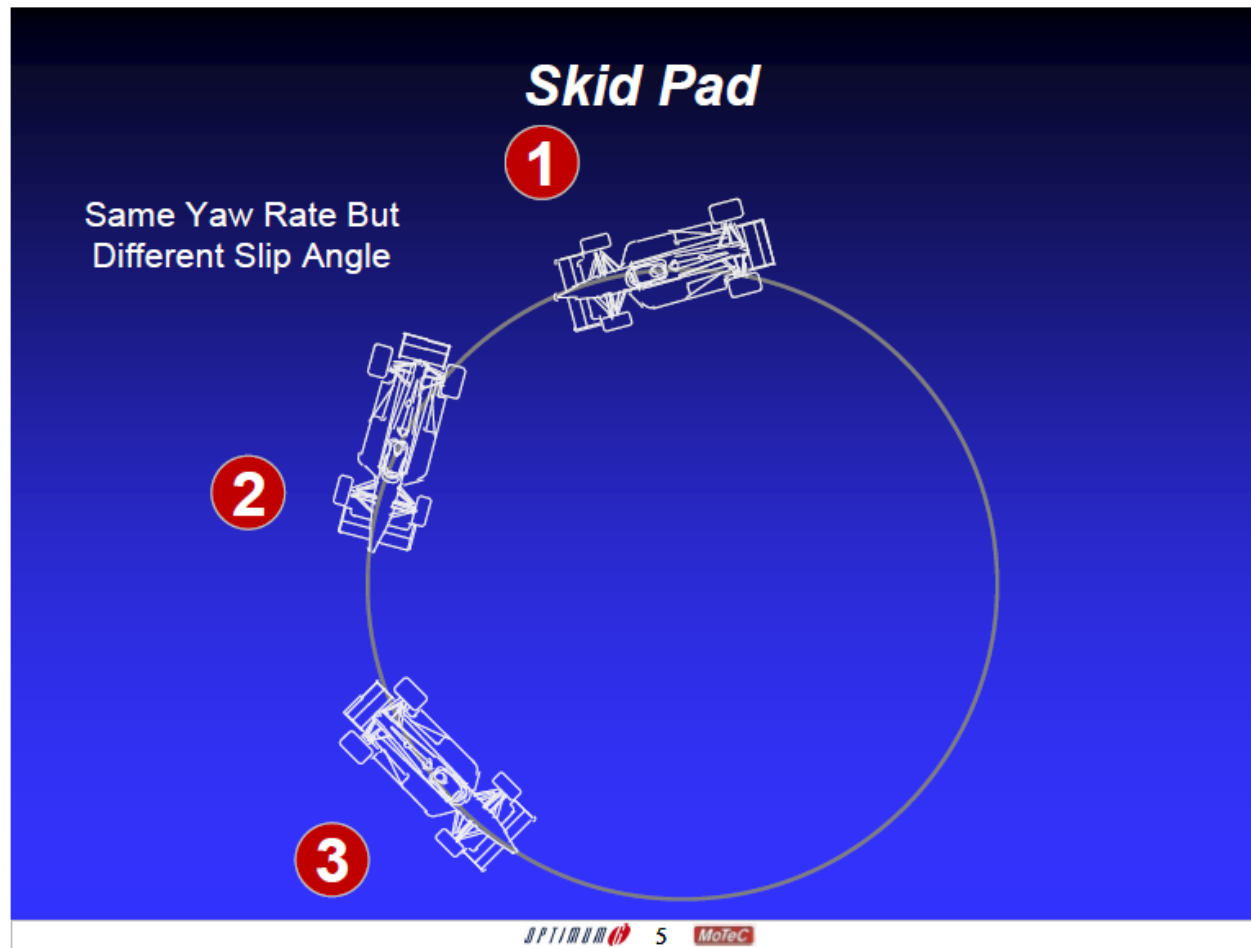
Slip Angle But No Yaw Rate



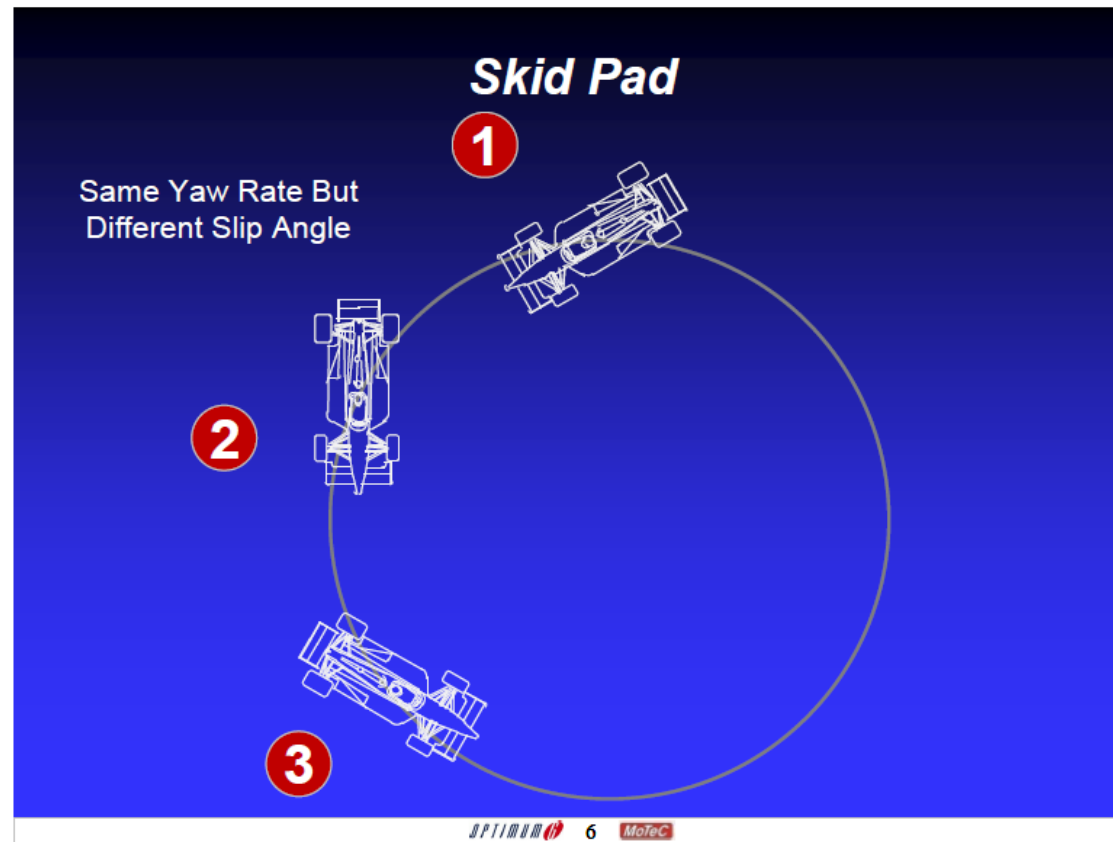
Example of a car drifting away from a wind or down a banked surface



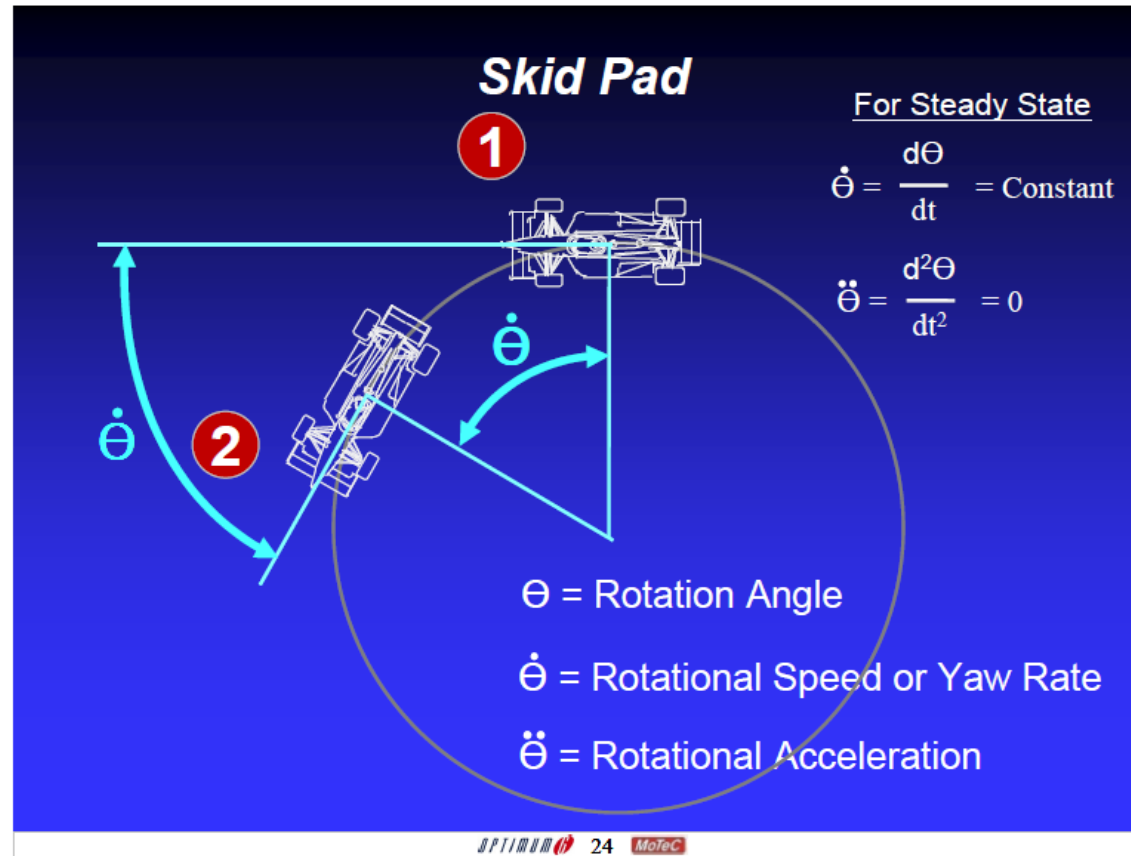
Yaw rate with 0° vehicle slip angle



Yaw rate with 10° vehicle slip angle



Yaw rate with 20⁰ vehicle slip angle



Handling behaviour considering Yaw Velocity and Acceleration

Calculating Yaw Rate

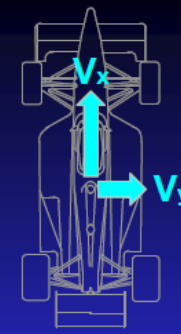
Known from
Speed Sensor

$$V_x = \dot{\theta} R$$

Known from
Lateral G Sensor

$$\text{Lateral G} = \frac{V^2}{R}$$

$$\text{Lateral G} = \frac{\dot{\theta} V^2}{V_x}$$



$$\dot{\theta} = \frac{\text{Lateral G}}{V_x}$$

Speed Sensor + Lateral G Sensor
gives Rotational Speed

OPTIMUM
25
MoTeC

Summary of relationships between Yaw and velocity

For a circular path eg the SMU steering pad, the yaw velocity can also be found from the laptime. eg

Time for 1 lap = 10 seconds

1 lap = 360°

So Yaw velocity = $36^{\circ}/\text{sec}$

If using a single wheel speed sensor then allowance must be made for this.

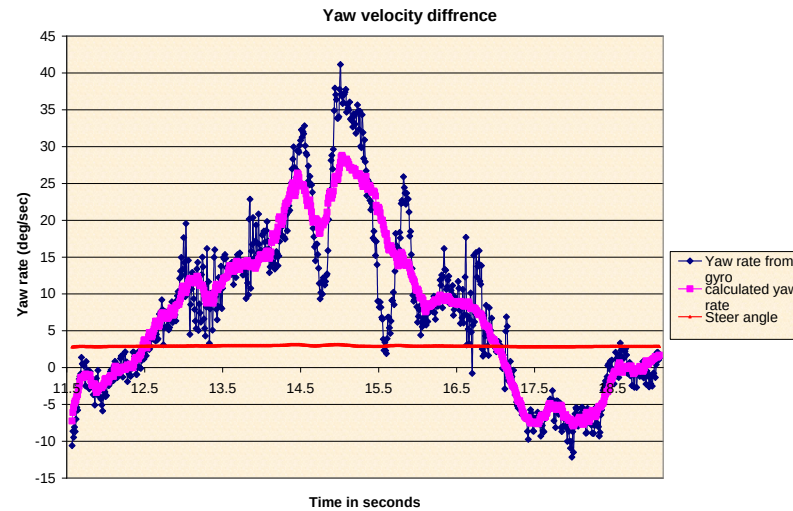
For example the Locost has a front track of approximately 1.4 m.

The wheel speed sensor is fitted to the inner wheel so that the vehicle speed when the inner wheel is tracking round a radius of 21m will be greater by a factor of $21.7/21$ ie 3.3% higher

eg an indicated 30 mph ie 13.33 m/s will actually be 13.77m/s

This approach can be used to investigate the behaviour of a car round a corner. Lateral Acceleration and velocity are known from data collected and so Yaw velocity can be calculated from Lat Acc/ Velocity

If the calculated yaw velocity is the same as the measured yaw velocity the car will be neutral steering and will maintain the cornering path. If they are not equal, however, the situation can only be a transient one as a yaw acceleration will be produced – if it were allowed to continue the car would spin (oversteer) or push straight on (understeer). This graph demonstrates the effect and was produced by Robin Perkins for his Woodstock Special Hill Climb car as part of his Major project in 2010, in which the car's tendency to oscillate around a neutral steer condition can be clearly seen.



Robin Perkins, 2010

“When a vehicle yaws less than expected, the term ‘understeer’ is used – the response of the vehicle is less than (‘under’) what might have been expected. When a vehicle yaws more than expected, the term ‘oversteer’ is used – the response of the vehicle exceeds (is ‘over’) what might have been discussed.” Blundell, M & Harty, D. (2004).