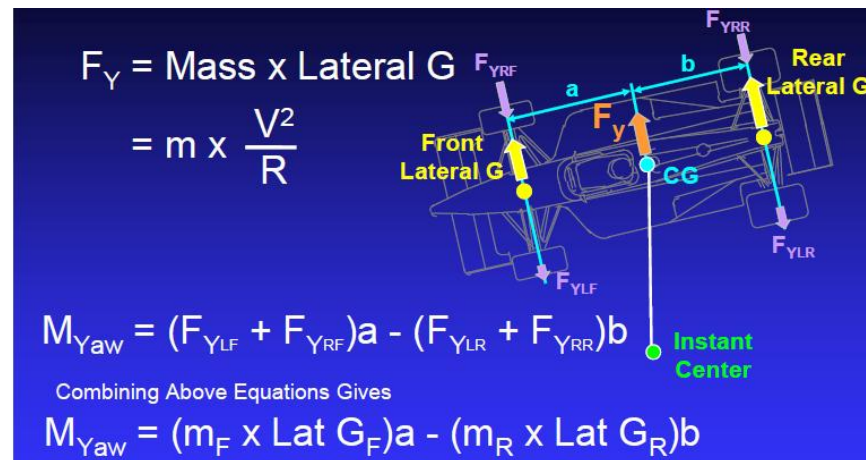


Oversteer and Understeer Pt 2

So far, what has been described has all been steady state behaviour when the car is cornering at relatively constant speed, Yaw velocity is constant and Yaw Acceleration = 0. All elements could be described as being in equilibrium.

The transition from steady state straight running to cornering then requires other aspects of the vehicle to be taken into account and can lead to a further range of descriptions of oversteer and understeer.



Optimum G

The balance between front and rear yaw moments

Looking at the problem in a similar way Sharp (2002) consider the balance in terms of front and rear tyre stiffnesses and the resulting yaw moments produced. This will give:

$(C_f \times \text{Slip Angle})$ is a force that is acting about the CG This creates a Yaw moment. If front and rear moments are not equal a yaw acceleration is produced dependent on magnitude of the difference in front and rear yaw moments and the rotational inertia of the car.

$$\begin{aligned}\text{Neutral steer} &= C_f \times a = C_r \times b \\ \text{Oversteer} &= C_f \times a > C_r \times b \\ \text{Understeer} &= C_f \times a < C_r \times b\end{aligned}$$

Transient oversteer/understeer behaviour

If the Yaw Moment, $M_{yaw} \neq 0$ the car will experience a yaw acceleration.

The magnitude of this yaw acceleration will depend on the rotational inertia of the car in the rotational equivalent of the linear form $F=ma$.

To determine the inertia of the car it needs to be supported on an oscillating rig and the inertia calculated from the natural frequency in rotation of the suspended car.

Calculating Yaw Acceleration & Moment

$$\ddot{\Theta} = \frac{d\dot{\Theta}}{dt} = \frac{d \frac{\text{Lateral G}}{V_x}}{dt}$$

Measured With
Inertia Rig

Calculated or
Measured with Gyro

$$\text{Yaw Moment} = \text{Inertia}_{\text{Yaw}} \times \ddot{\Theta}$$

Yaw Acceleration + Yaw Inertia

gives Yaw Moment

$$M_{Yaw} = I_{Yaw} \times \ddot{\Theta}$$

Yaw Moment = Inertia_{Yaw} x Yaw Acceleration

To Increase Yaw Acceleration

1. Increase Yaw Moment
2. Decrease Yaw Inertia
3. Increase Yaw Moment & Decrease Yaw Inertia

Within the limits produced by the maximum achievable response time of a driver, the faster a car can accelerate in rotation the more responsive it will be.

How could 1 and 2 be achieved?

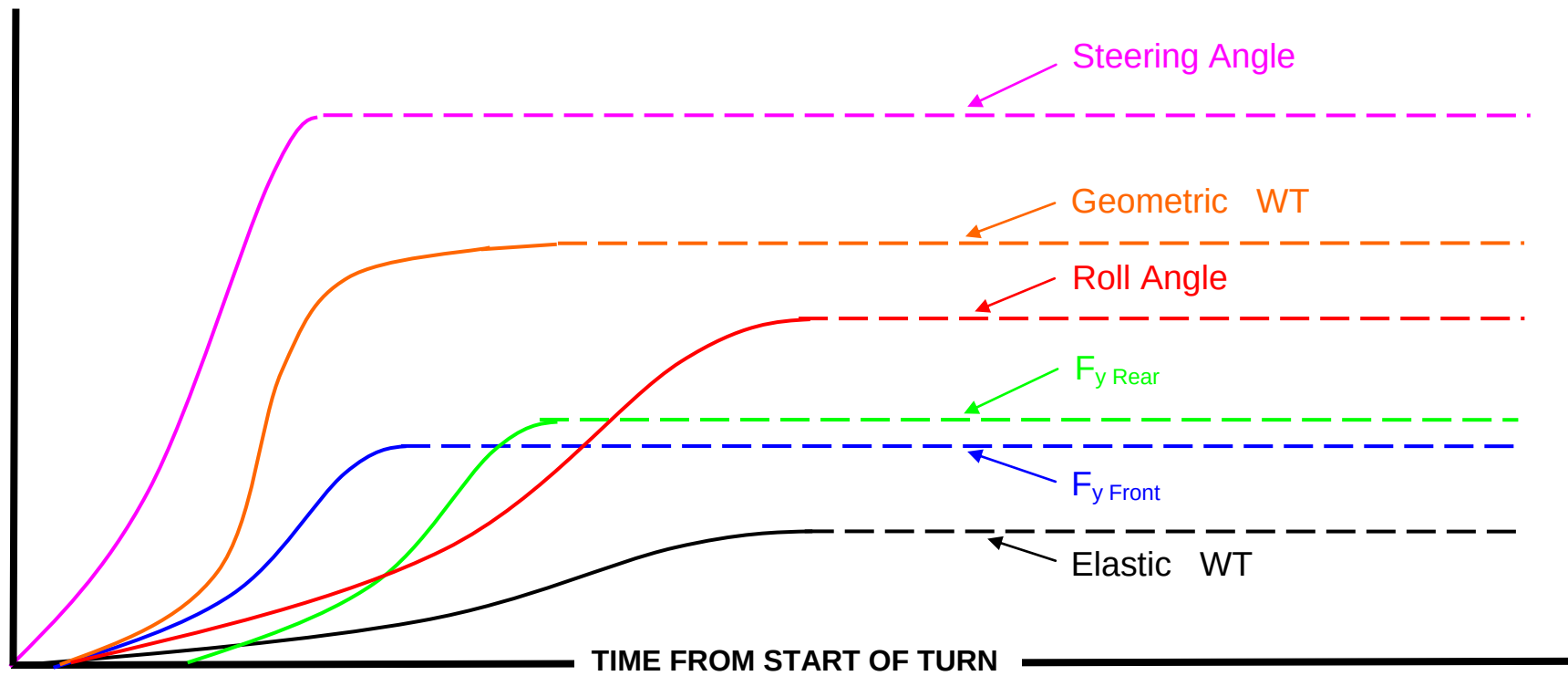
A yaw acceleration is required to make the transition from straight running to cornering.

If data from a yaw velocity sensor is differentiated then this will give Yaw Acceleration.

When changing direction there will be a yaw acceleration. The transient behaviour could be described by determining the yaw acceleration required to change from one heading to another in the time period of the manoeuvre and comparing that with the yaw acceleration actually measured.

Claude Rouelle, 2008 Suggests that,:

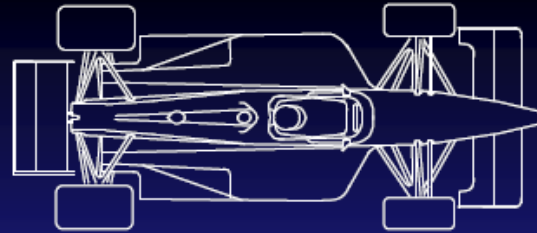
- *There is no such thing as understeer or oversteer*
- *There is only under and over yaw acceleration.*
- *You can get understeer (which means under yaw acceleration) because;*
- *You do not have enough front tire grip*
- *You have too much rear tire grip*
- *You do not have the ideal weight (and aero) distribution (distance a and b)*
- *You have too much yaw inertia*



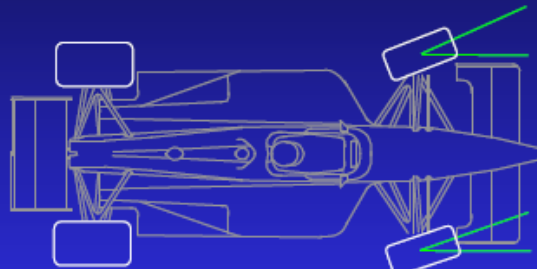
Sequence of events during cornering

- Steering turned to initiate cornering creating a slip angle in front tyre
- Front tyre builds up lateral force (F_y Front) after initial $\frac{1}{4}$ rotation delay to distort tyre structure
- Geometric weight transfer developed proportional to front lateral force
- Vehicle starts to roll in response to lateral acceleration produced by front lateral force
- Elastic weight transfer builds up in response to roll angle
- Rear tyre lateral force (F_y Rear) builds up in the same way as the front increasing level of geometric weight transfer
- Increased rate of vehicle roll and elastic weight transfer in response to rear lateral force build up
- Steady state roll angle achieved.
- Dotted lines represent conditions at steady state which are likely to oscillate in practice until damped to constant value

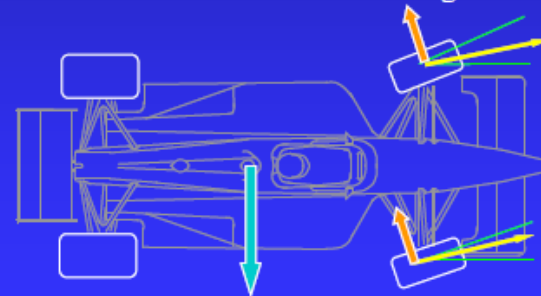
Tire Lateral Force Sequence in a Corner



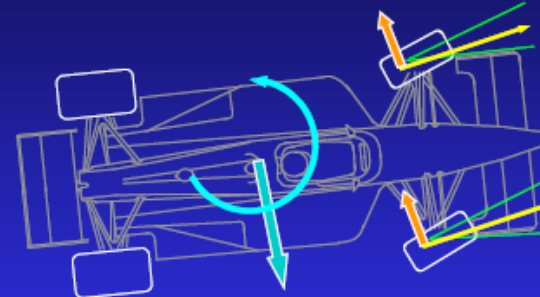
1. Straight away



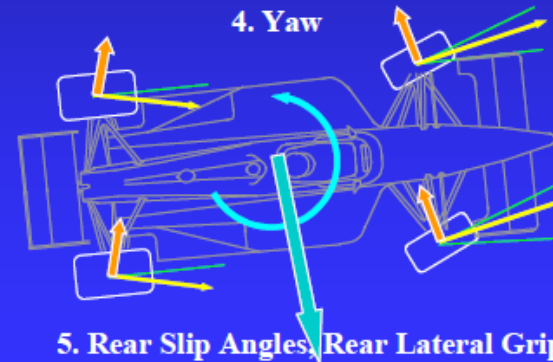
2. Front Wheel Steering



3. Front Wheel Slip Angle, Front Lateral Grip, Lateral Acceleration

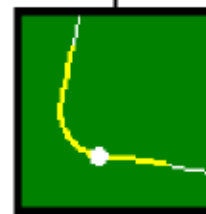
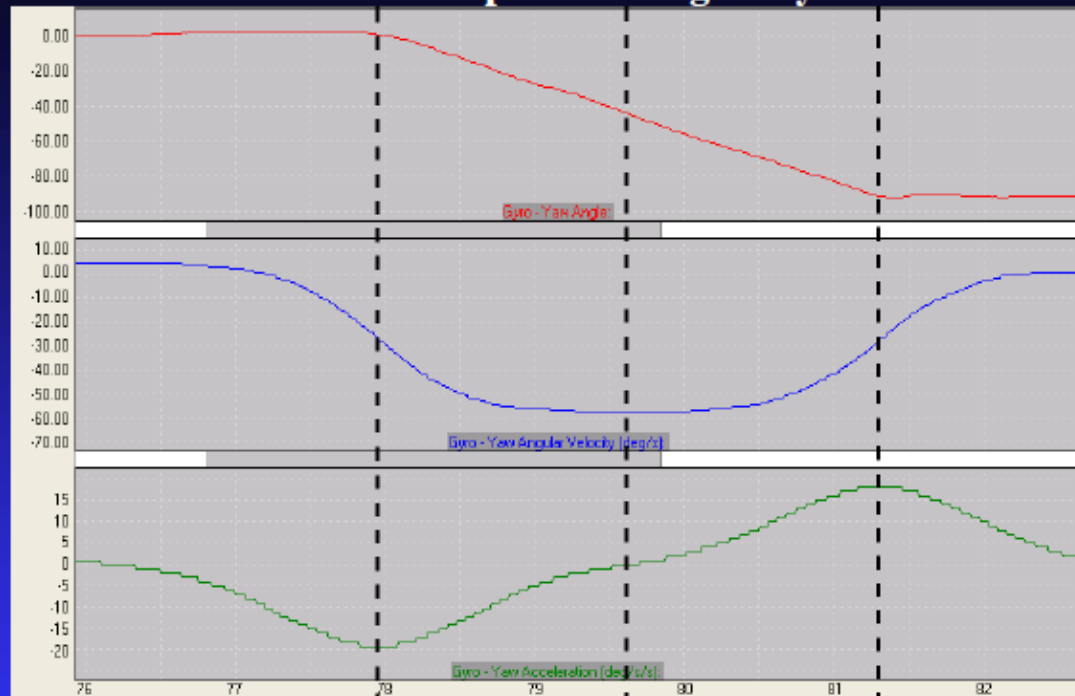


4. Yaw

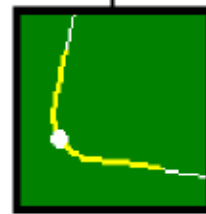


5. Rear Slip Angles, Rear Lateral Grip and More Lateral Acceleration

Example Of Using A Gyro Sensor in A Corner



Corner Entry



Mid Corner



Corner Exit

Yaw Angle

$$\int Yaw Velocity dt$$

Yaw Velocity

Yaw Acceleration

$$\frac{d(Yaw Velocity)}{dt}$$

Claude Rouelle, 2008 goes on to say

Vehicle Cornering Performance

- Race car performance is not only about maximum lateral acceleration it is also about longitudinal acceleration.
- Lateral and longitudinal accelerations are functions of the tyre's lateral and longitudinal properties and the ability of the driver to exploit them. It is also about yaw acceleration.
- The yaw acceleration is a function of the car's yaw inertia and the car's yaw moment
- The yaw inertia needs to be measured on a inertia test rig or determined by calculation

- The yaw moment is a function of the tyres's longitudinal and lateral forces, the wheelbase the front and rear tracks.
- The ideal yaw acceleration on a steering pad (steady state) is 0
- The ideal yaw acceleration required in transient manoeuvres depends on the speed, and the radius of the corner being negotiated

References

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- Dixon, JC (1996) *Tyres, Suspension and Handling* 2nd ed. SAE, Warrendale
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- Rowley, W (2005) *An Introduction to Race Car Engineering* 3rd ed. Rowley Race Dynamics, Calgary
- Sharp, R (2002) Course notes MSc Cranfield
- Rouell, C (2008) Course notes Optimum G Vehicle Dynamics course
- Perkins, R (2010) Major project Dissertation SMU

Summary of Understeer/Oversteer Descriptions

1.Slip Angles

Front slip angle greater than rear = understeer

2.Tyre stiffness and CG position

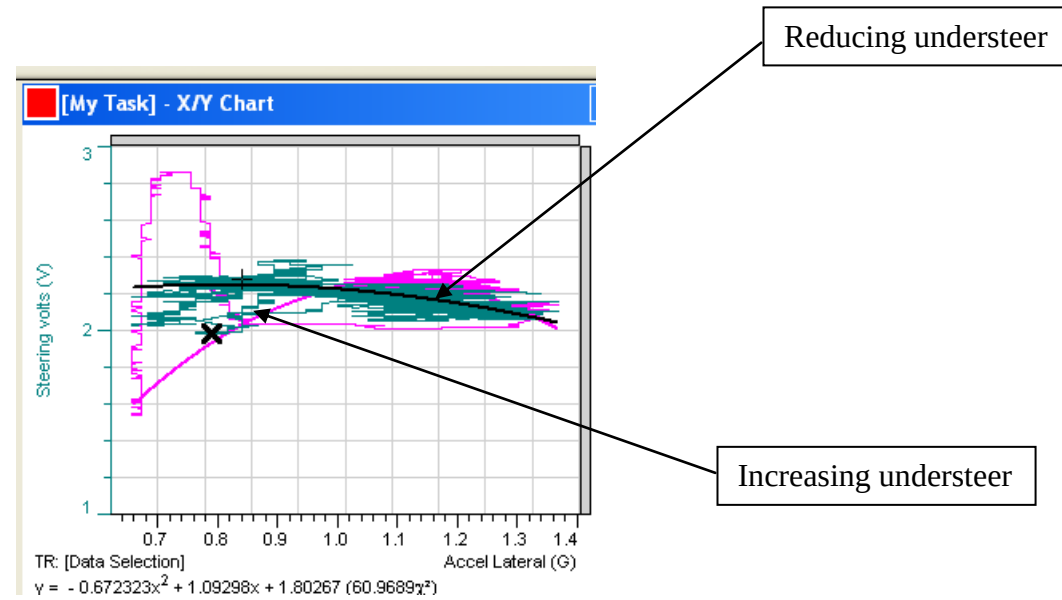
$$C_f \times a < C_r \times b \quad (\text{Sharp , 2002})$$

C_f (N/deg) is a force that is acting about the CG This creates a Yaw moment. If front and rear moments are not equal a yaw acceleration is produced dependent on magnitude of the difference in front and rear yaw moments and the rotational inertia of the car.

3. Yaw Acceleration

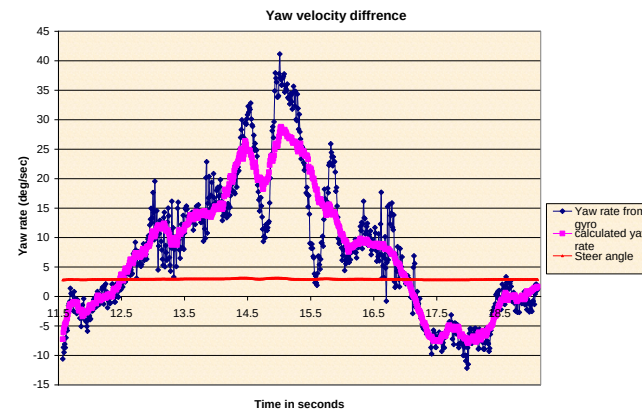
When a turn is instigated, if the measured yaw acceleration is less than required to make the transition then understeer is indicated. For steady state cornering Yaw acceleration should be zero

4. Understeer gradient



6. Yaw Velocity

Comparison between measured and calculated yaw velocity – if measured is less than calculated then understeer is occurring.



Robin Perkins, 2010

7. SAE definition

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

8. Load Splits

Predictive – if split at front is greater than rear than understeer will be indicated if all else is equal!