

BSc /HND Automotive and Motorsport Engineering

Data Acquisition and Dynamics Session 2

Roger Dowden
roger.dowden@uwtsd.ac.uk

Handling

- **Handling** is different to maximum steady state lateral acceleration (“grip”)
- Prodrive (a top UK Automotive and Motorsport consultancy) has a working definition:
 - *“a quality of a vehicle that allows or even encourages the operator to make use of all the available grip”*

Handling

More 'emotional' definitions can include:-

"Confidence" (consistency / linearity to inputs)

"Fun" (high yaw gain, high yaw bandwidth)

"Fluidity" (yaw damping between manoeuvres)

"Precision" (disturbance rejection)

Steady State

The terms **NEUTRAL STEER, OVERSTEER** and **UNDERSTEER** are commonly used to define another aspect of Handling which is the driver's perception of the steady state steering behaviour of the cornering car. There are a number of ways to describe this.

Review

First, a couple of slides to clarify the terms that are used in analysing vehicle behaviour.

Road wheel and steering wheel angle



Road wheel
angle



Steering
wheel angle

Basic Definitions

To start with, the following terminology is used by the Society of Automotive Engineers (SAE) in the US

$$\text{Overall Steering Ratio} = \frac{\text{Steering Wheel Angle}}{\text{Road Wheel Angle}}$$

So

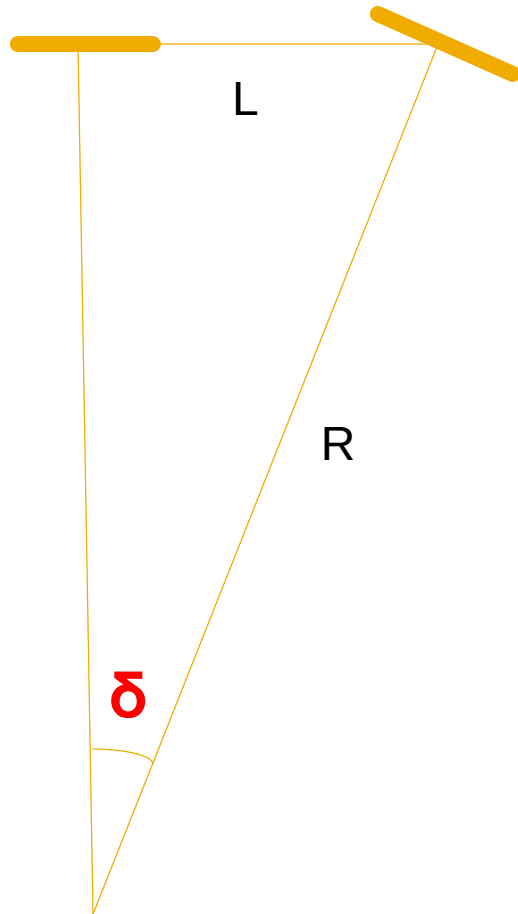
$$\text{Road Wheel Angle} = \frac{\text{Steering Wheel Angle}}{\text{Overall Steering Ratio}}$$

Neutral Steer

The Society of Automotive Engineers (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 road wheel angle] equates to the Ackerman steering angle for a given radius of turn.*

Ackerman Steering Angle



Ackerman steering angle δ 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

$$\delta = L / R \text{ for small angles.}$$

Which means ...

If the amount you have to turn the steering wheel to go round a particular corner at speed is the **same as** when travelling at very low speed (Ackerman Steering Angle) then that is **neutral steer**

How do we find the Ackerman Steering Angle from measured road data ?

$$a_y = V^2 / R \quad .$$

V and a_y can be measured channels giving :

$$\text{Radius of turn} = V^2 / a_y$$

The ackerman steering angle can then be found be compared with actual road wheel angle to determine the degree of understeer being experienced.

Understeer

*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*

Understeer

*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*

Which means....

If the amount you have to turn the steering wheel to go round a particular corner at speed is **greater than** when travelling at very low speed then the car is **understeering**

Oversteer

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

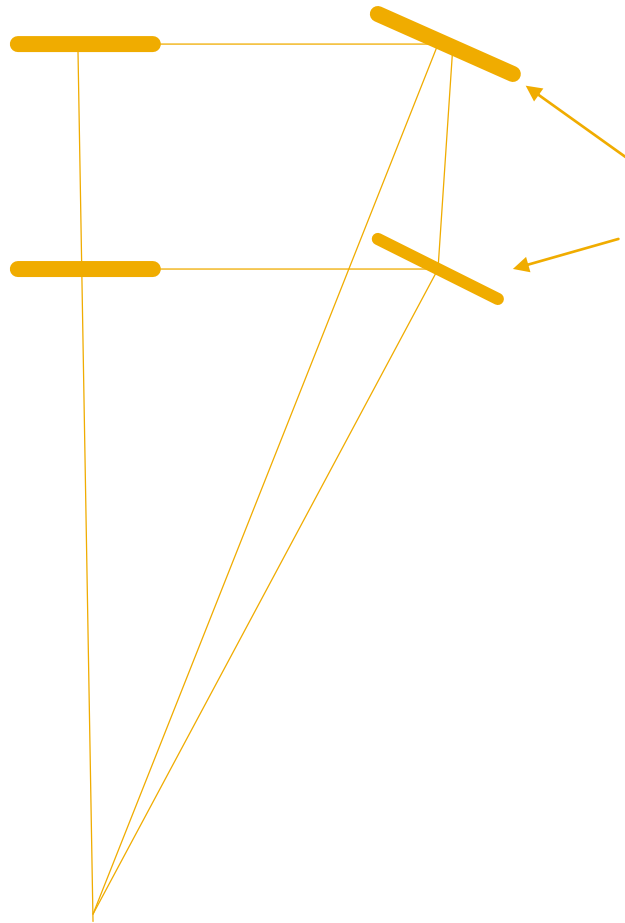
Which means....

If the amount you have to turn the steering wheel to go round a particular corner at speed is **greater than** when travelling at very low speed then the car is **understeering**

Ackerman Steering Geometry is not Ackerman Steering Angle!

The **Ackerman Steering Geometry** is the design of the steering mechanism that enables both inner and outer steered wheels to have the correct steered angle so that they both drive round the same turn centre. In line with the rear axle with no slip angle.

Ackerman Steering Geometry

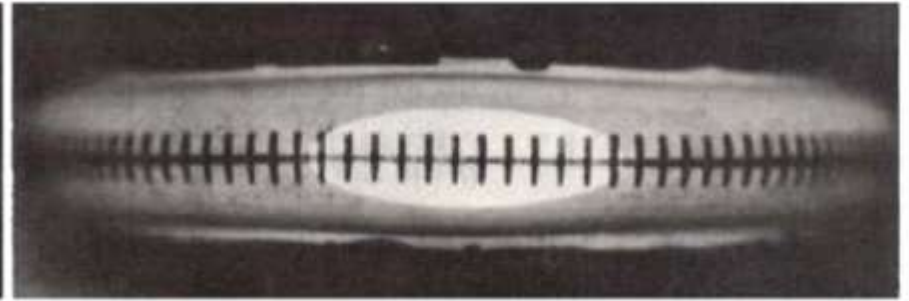
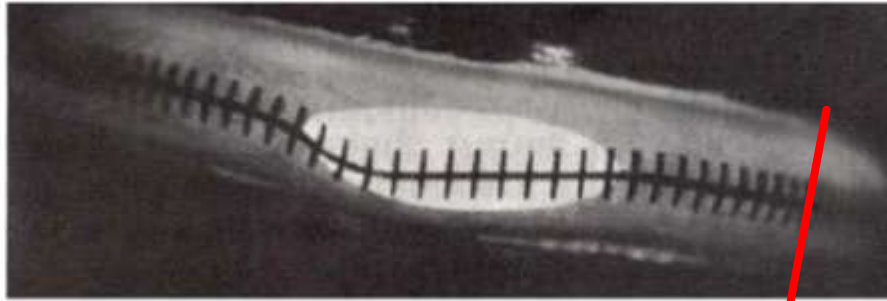


Inner and outer wheels have a different steering angle to ensure both track round exactly the same point on a transverse line through the rear axle

What determines the handling balance ?

One way of defining the handling balance of a car is to describe it in terms of the slip angles of the front and rear tyres.

Slip angle



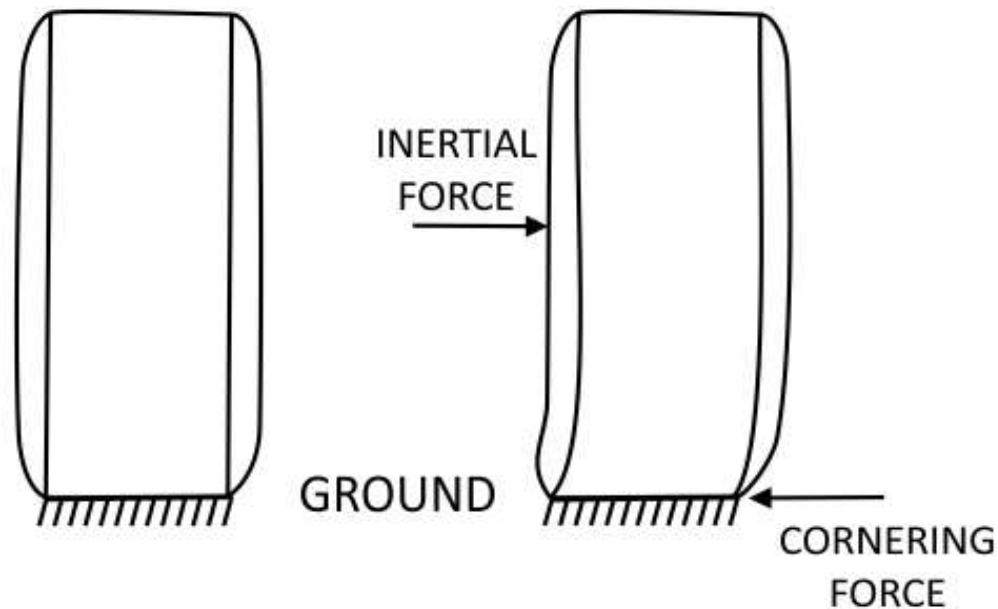
Wheel steered clockwise
ahead

Wheel running straight
ahead

Direction of Travel

(CLARK, Samuel; 1971, Mechanics of Pneumatic Tires).

Steered tyre generating a side force to overcome inertial force



Tyre Testing

See 'Tire Force Testing' video in Background Information section of this module .

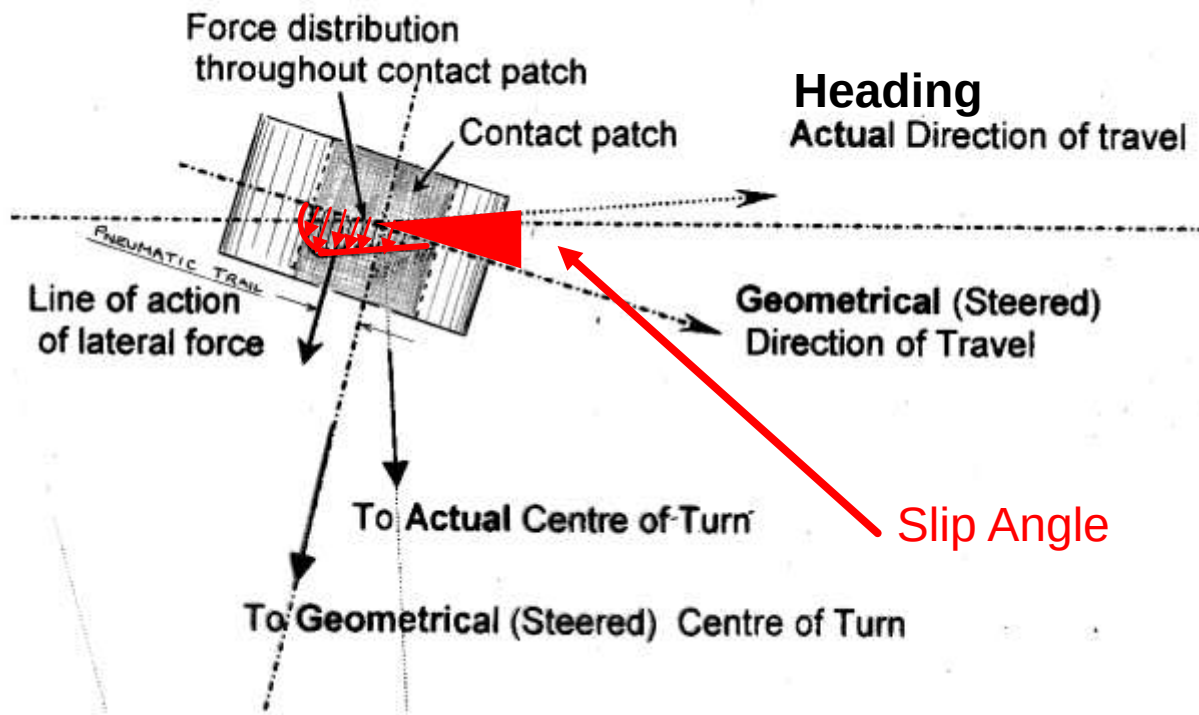


How does a tyre generate a cornering force?

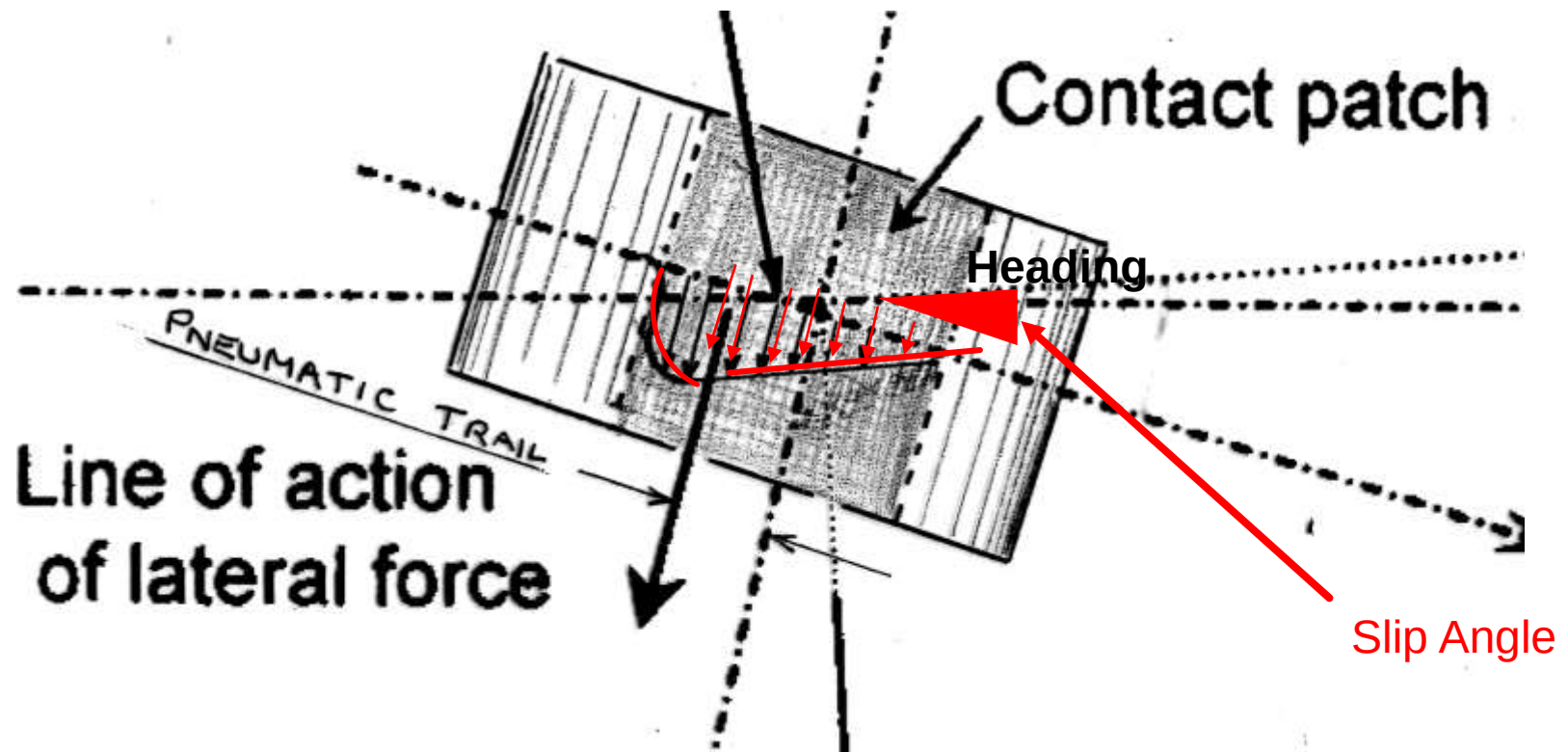
As the tyre steers the tyre distortion generates the side force at the contact patch and so the greater the distortion, the greater the lateral force that is generated

Slip Angle in more detail

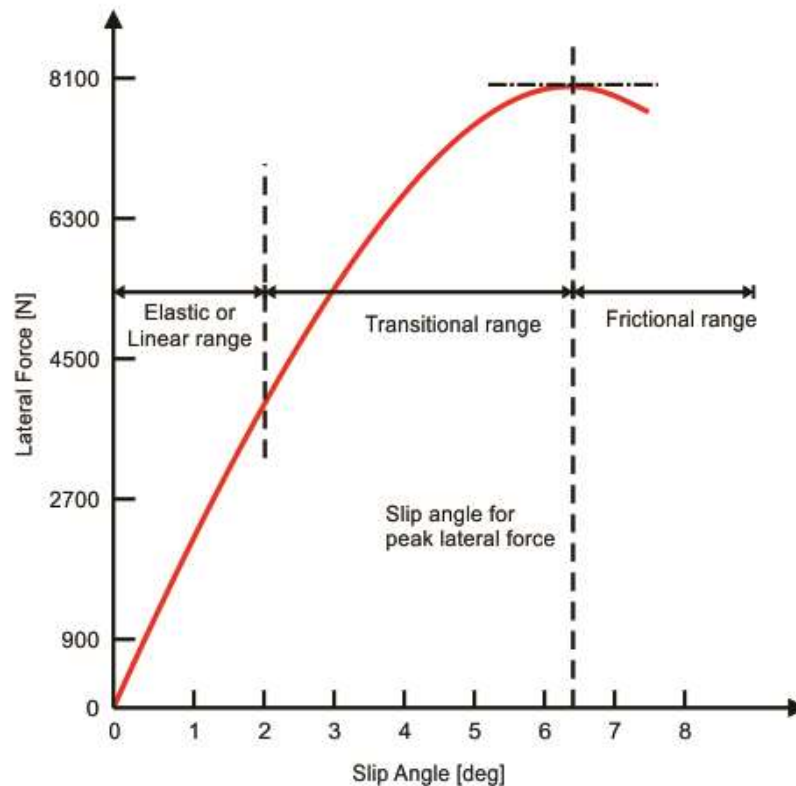
When the wheel is steered a tyre slip angle which is the difference between the Heading (the actual direction of travel) and the direction it is steered. It results in distortion of the tyre



Slip Angle

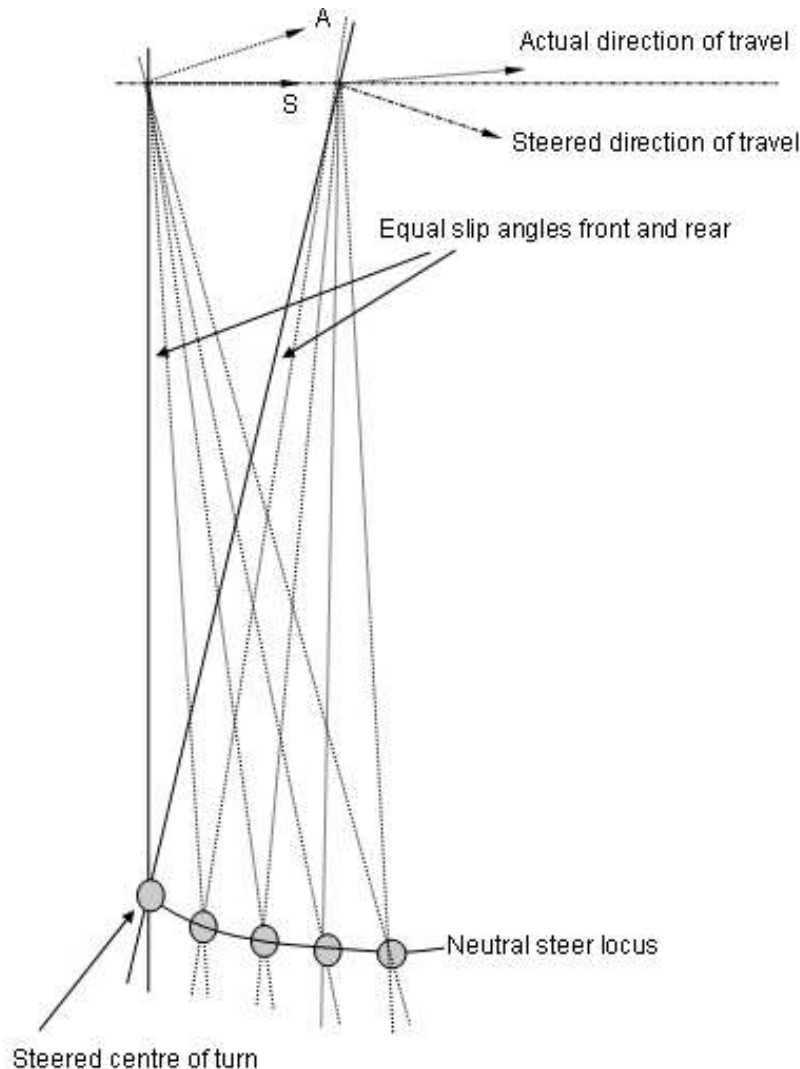


Lateral Force Vs Slip Angle



MILLIKEN & MILLIKEN, Race Car Vehicle Dynamics

What is the Neutral Steer Locus?



Homework : Try this construction for yourself (Make wheelbase 4cm and radius of Turn 20 cm and then put in 2 degree increments of slip angle)

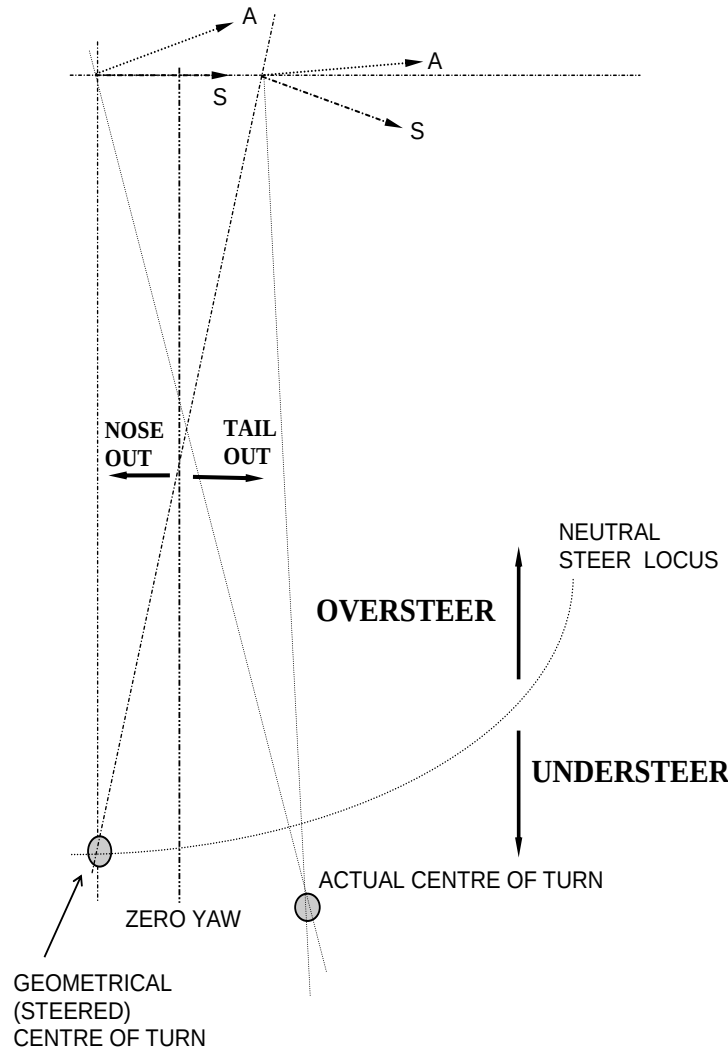
What is meant by 'Tail Out' attitude ?



Race car driving round a circle in a 'Tail Out' attitude

Geometrical method of demonstrating oversteer and understeer based on slip angle

Lines are drawn perpendicular to the actual direction of travel for front and rear wheels. Where they cross is the actual centre of turn.



If the centre of turn is closer to the car than the neutral steer locus the car will be oversteer and if it is beyond the locus it is understeer .

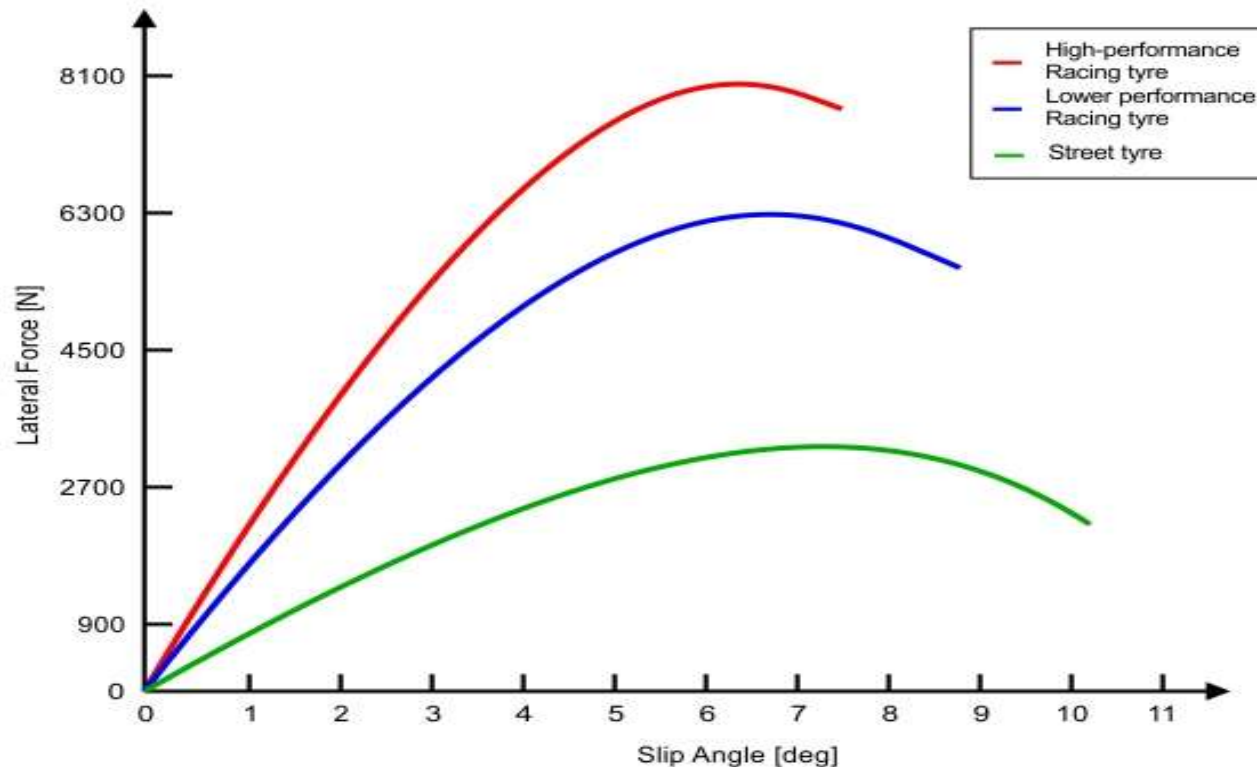
So the car shown is understeer with tail out attitude.

All cars go from a nose out to tail out attitude as speed increases

What determines the slip angles that are generated?

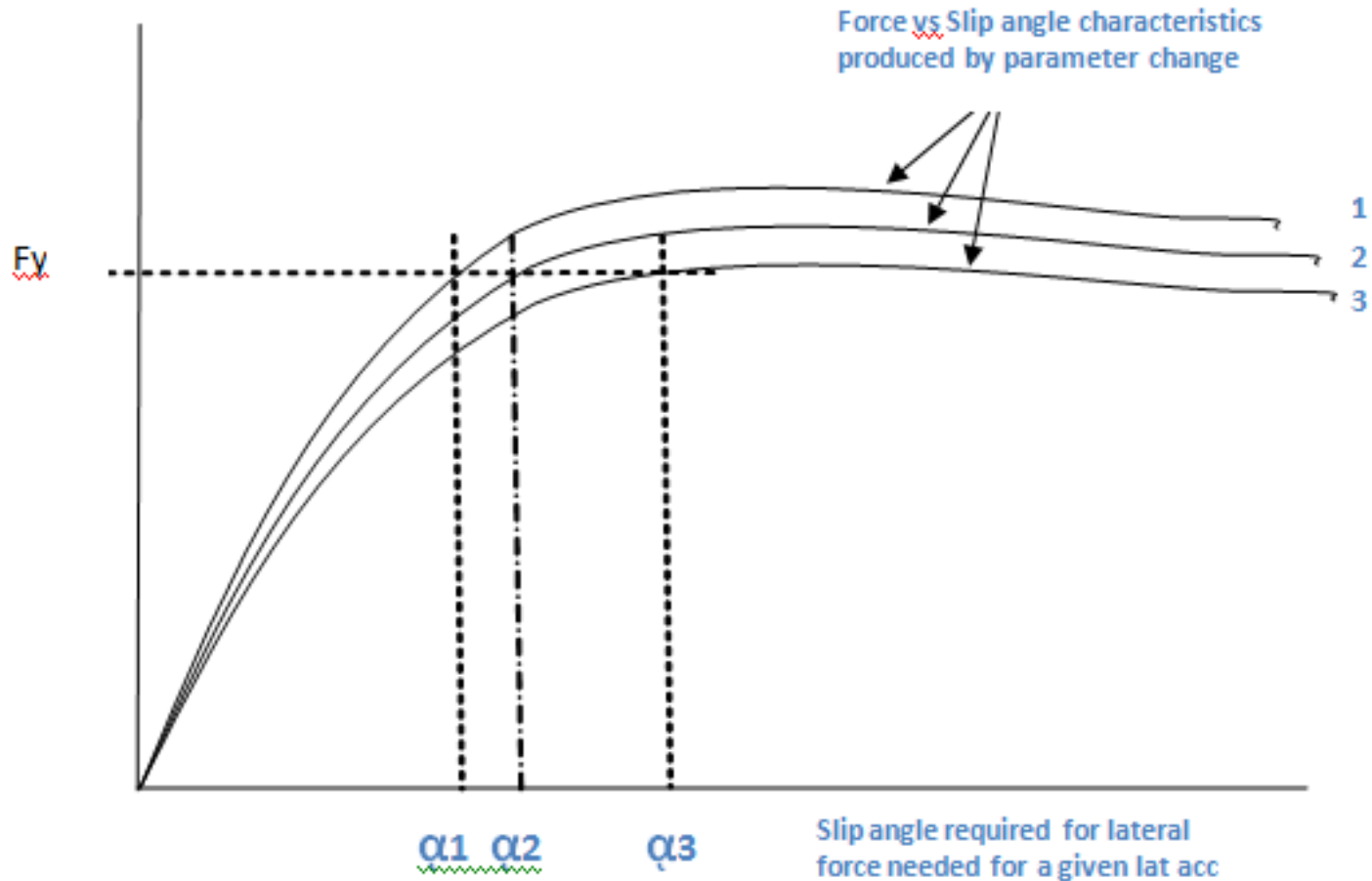
The performance characteristics of the tyres at each end of the car determine what slip angle is required to provide the required lateral force for a given corner and hence the car's handling balance

Range of Tyre Performance Characteristics



MILLIKEN & MILLIKEN, Race Car Vehicle Dynamics

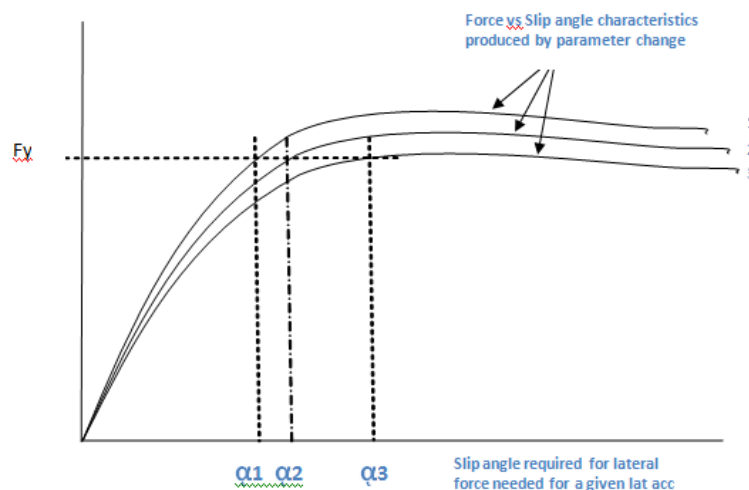
What determines the slip angles that are generated?



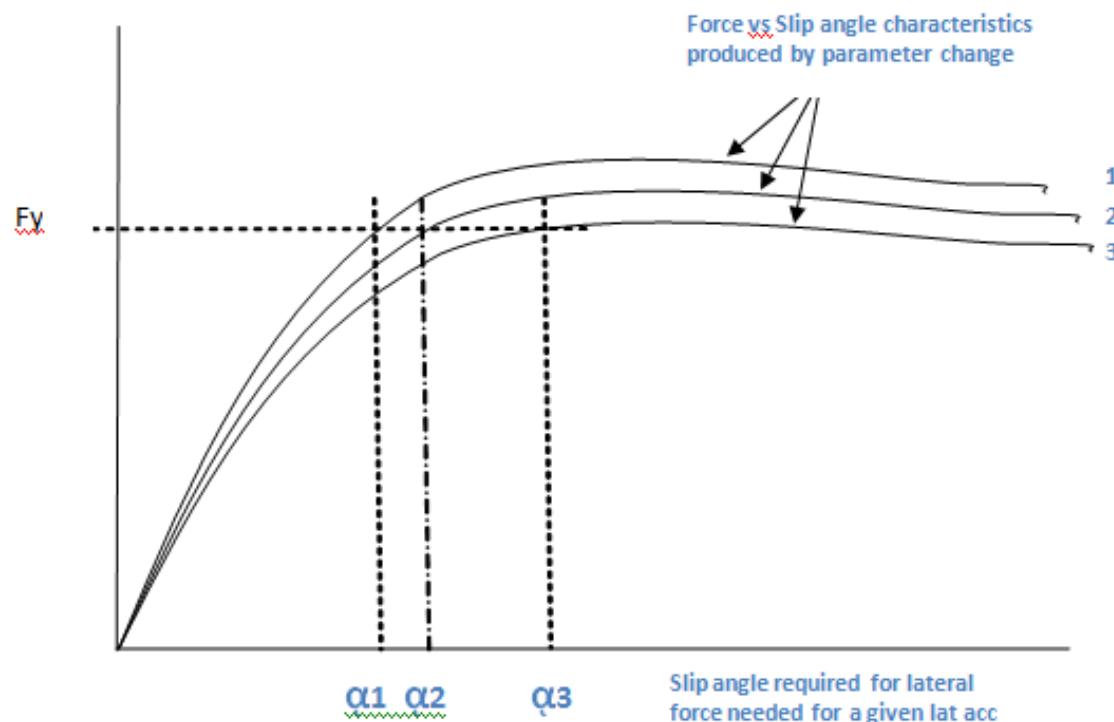
Typical tyre performance characteristics possible in one tyre.

Range of Tyre Performance Characteristics

Consider the tyres on the front axle of a car where the force required to corner at the required rate is F_y . If the tyres on that axle have characteristic 3 the slip angle required to produce the force will be α_3



If, as the result of a suspension or tyre changes, the tyres on the axle now move to Characteristic 2 the slip angle required to produce the same force will be α_2



How do changes to the tyre performance characteristics change handling balance?

If the car had originally had an understeering characteristic and the rear tyre performance characteristic was not changed the difference between front and rear slip angles would be less and so the level of understeer would be less.

How do changes to the tyre performance characteristics change handling balance?

If the car had originally had an understeering characteristic and the rear tyre performance characteristic was not changed the difference between front and rear slip angles would be less and so the level of understeer would be less.

Summary

- A car's steady state handling characteristic can be described by the relationship between front and rear slip angles
- The slip angles are generated by the cornering tyre.
- The slip angles are determined by the performance characteristics of the tyre.
- In the next session we will see how vertical tyre load determines the lateral force generated.