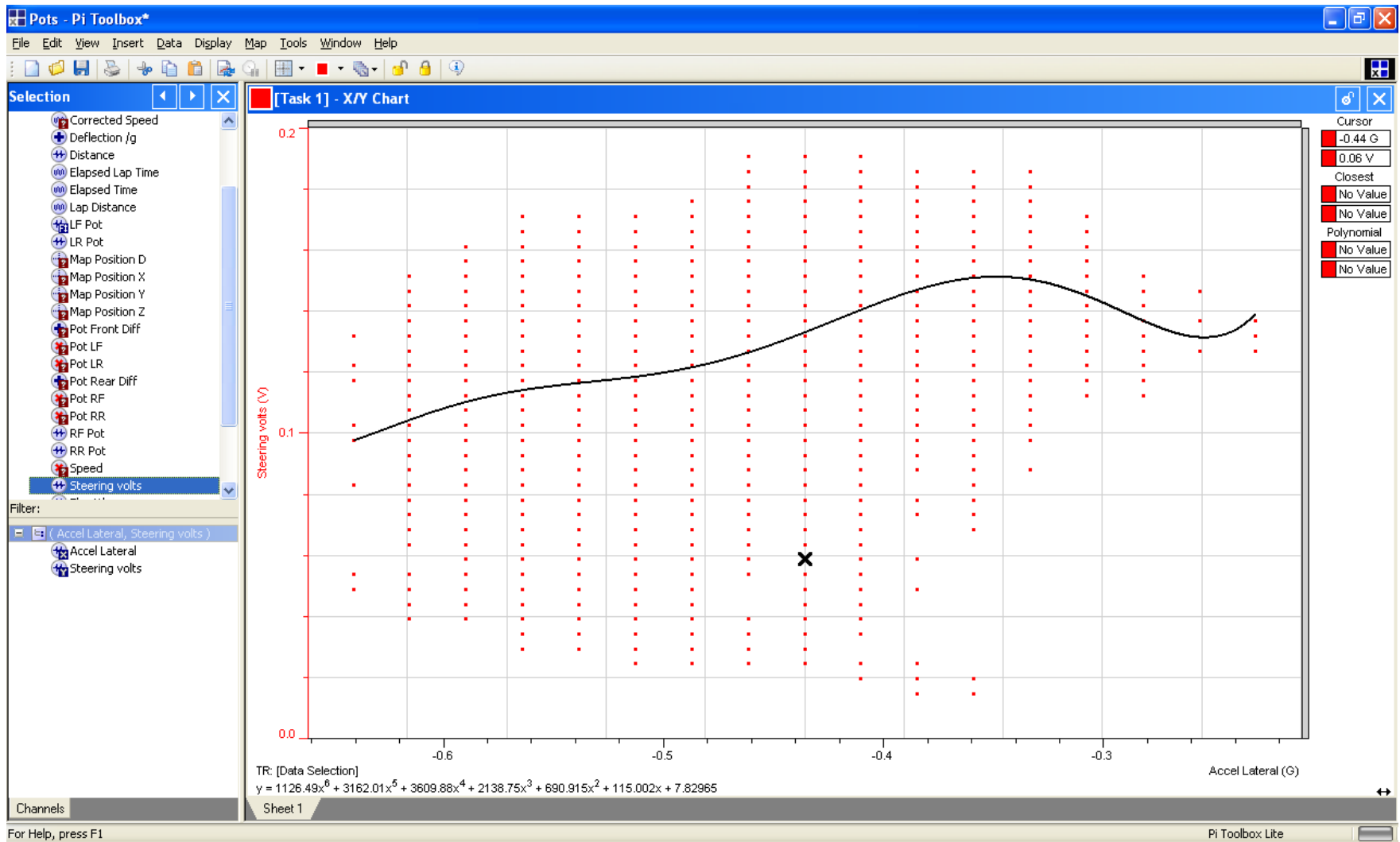


The value of a tyre model

A tyre model could be seen as a more complex equivalent of the equation for a trend line for a cloud of data points.



$$y = 1126.49x^6 + 3162.01x^5 + 3609.88x^4 + 2138.75x^3 + 690.915x^2 + 115.002x + 7.82965$$

The Tyre Model

If the operating conditions of the tyres are known it should be possible, with an accurate model, to predict the lateral force produced by each tyre and hence determine the handling balance and performance of a car.

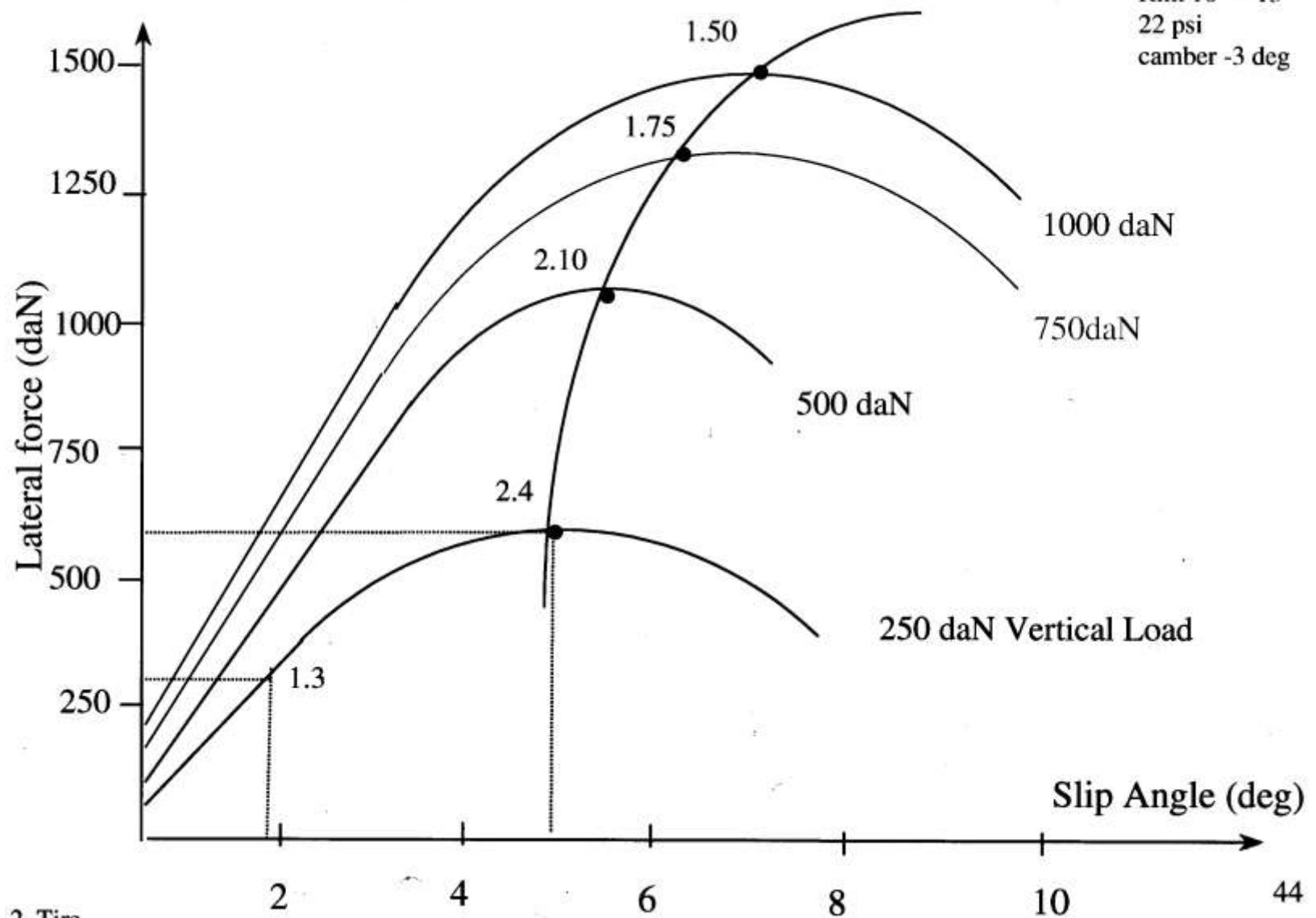
But also ...

Knowing a tyre's performance characteristics it will also be possible to determine the required suspension geometry, spring rates, ARB rates and damper characteristics to achieve the required load distributions and so achieve the required vehicle performance.

Also

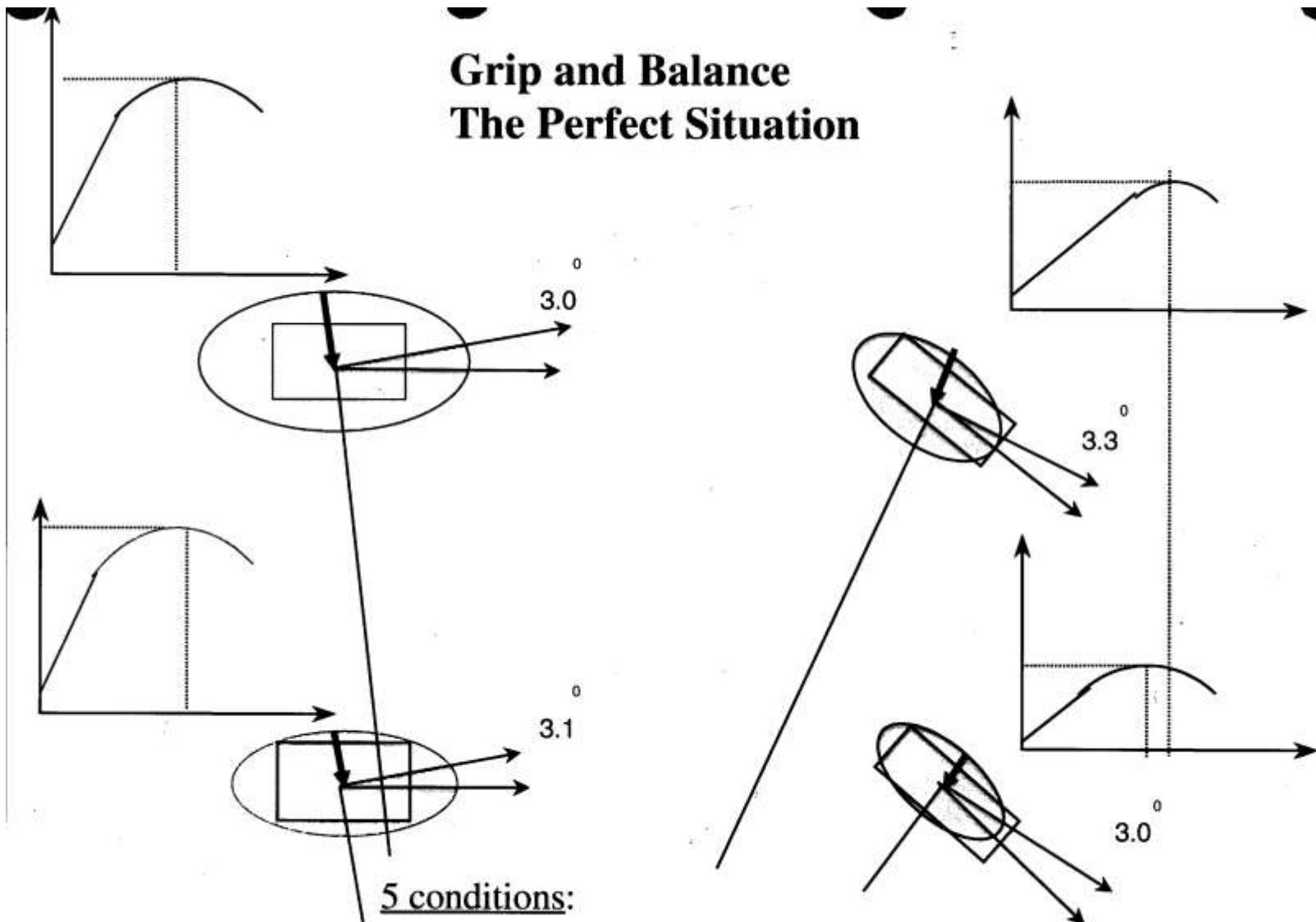
Ideal camber angles, the relationship of inner and outer steered angles and camber angles etc.

Lateral force Vs Slip Angle for different Normal Load



2. Tire

Grip and Balance The Perfect Situation



5 conditions:

Car balance (similar front and rear slip angles)

Maximum grip of each 4 tires (on the edge of the traction ellipse)

2. Tire

49

Prediction of forces generated by the tyre

To achieve such graphs in practice a model has to be produced that simulates the behaviour of the tyre under the complex conditions that a real tyre operates under.

Tyre Models

Pacejka suggests four ways that tyre performance can be modelled. They range from the use of experimental data through to the complex physical models based on the physical structure of the tyre.

from experimental data only	using similarity method	through simple physical model	through complex physical model
fitting full scale tyre test data by regression techniques	distorting, rescaling and combining basic characteristics	using simple mechanical representation, possibly closed form solution	describing tyre in greater detail, computer simulation, finite element method

1. Tyre Modelling

An example of an empirical model that makes use of experimental data to determine tyre grip is that described in Pacejka's book *Tyre and Vehicle Dynamics*, (2006) 2nd ed. Butterworth-Heinemann, Oxford

The general form of this equation is given on the following slide. Using what is called the Magic Formula which is widely used in the automotive industry . Note that the most significant factor is F_z the vertical load.

Pacejka's Magic Formula

The basic expression for side force is given by :

$$F_y = D \sin[C \arctan - E\{B\alpha - \arctan(B\alpha)\}]\alpha$$

Where:

C shape factor

E curvature factor

D peak factor in 'Magic Formula'; dissipation function

F_y lateral tyre force

Stiffness factor $B = C_{F\alpha} / (CD)$

Peak factor $D = \mu F_z$ ($= F_{y,peak}$)

Where:

μ coefficient of friction

F_z vertical (normal) tyre force (load) (>0)

Use of the Magic Formula

Used in many simulation programs such as Adams, Race Sim and Pi Sim where many programmable constants are used in addition to the base formula.

Lower cost programs such as the Bosch Lap Sim Expert software only use a small number of constants.

Both Bridgestone and Goodyear have 'subscribed to the club' in that they make use of the Magic Formula and so its use is widespread in motorsport.

Burrell Formula

Warren Rowley adopts a similar empirical approach but has adopted what he calls the Burrell Formula that is detailed in Wan32 as

$$F = F_{\max}(1 - a^{-L/L_0})$$

Where:

:

$F_{\max}$, a , L_0

$F_{\max}$ = constant

a = constant

L = load seen at contact patch

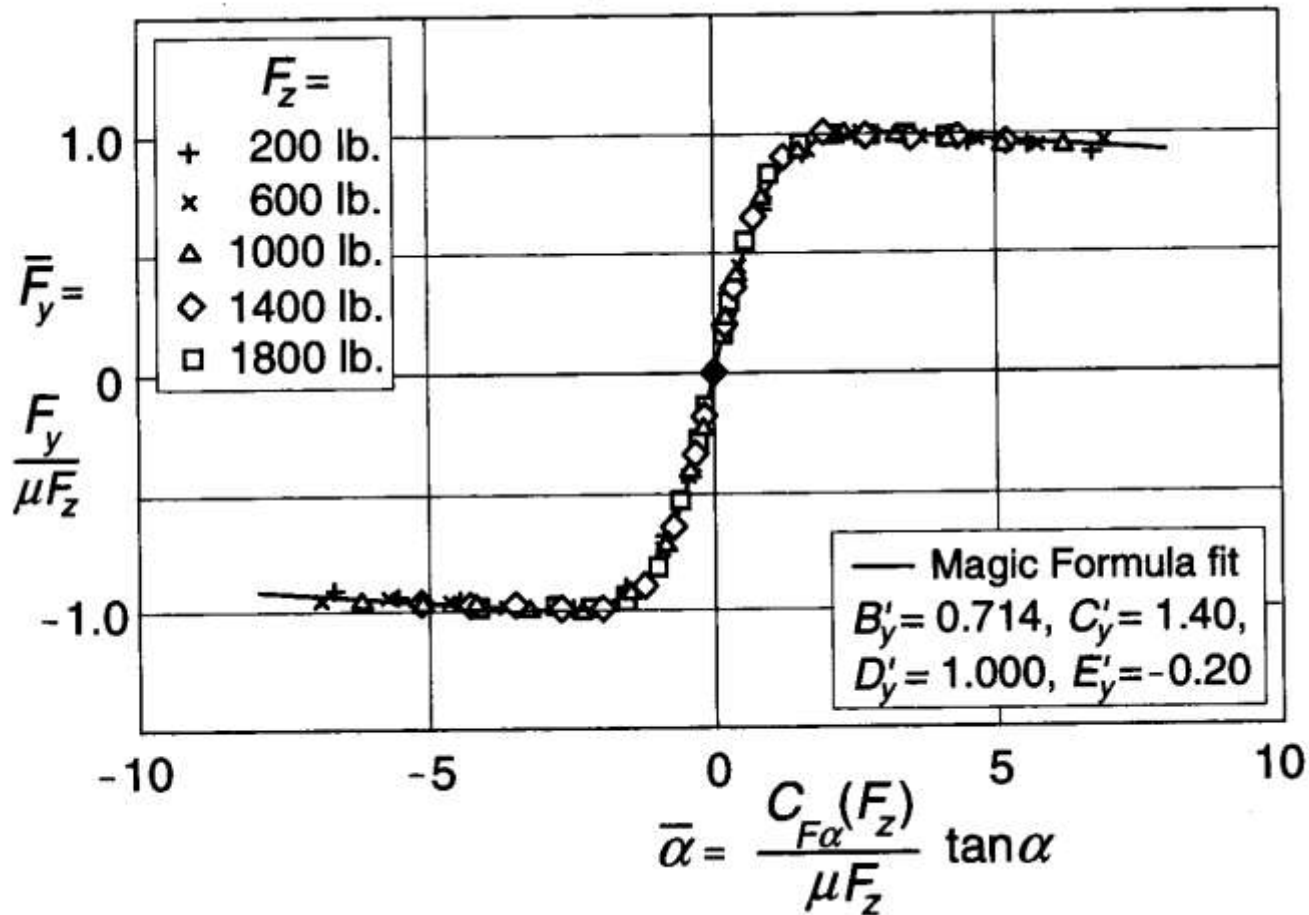
L_0 = reference load

F reference $(a - 1/a)F_{\max}$

2. Similarity Method

The second category of tyre model detailed by Pacejka is classed as using similarity method. This method is based on observation that pure slip curves remain approximately similar in shape when the tyre runs at different conditions to the reference conditions.

Non Dimensional Tyre Curves



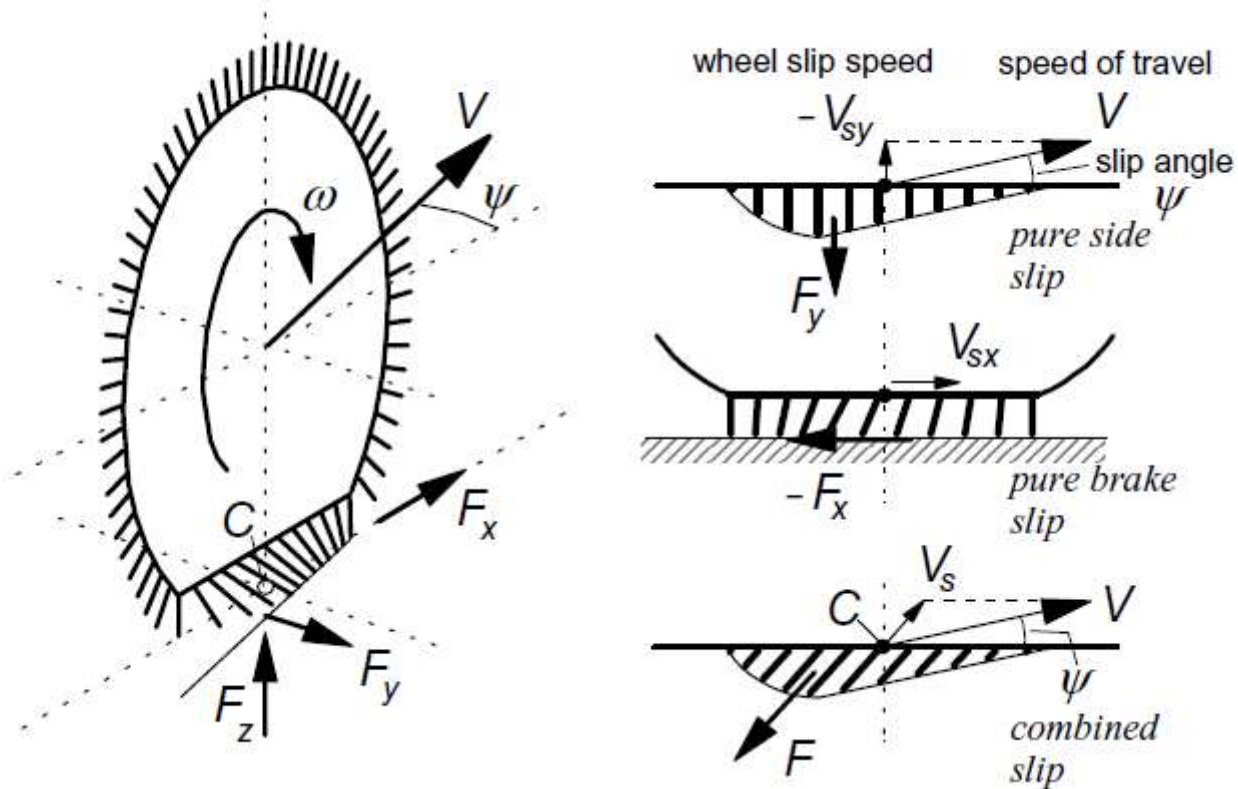
3. Mechanical Representation

The third group is what Pacejka describes as using simple mechanical representations. The best known of these is the brush model in which the tyre characteristic can be represented by the physical characteristics of brush bristles

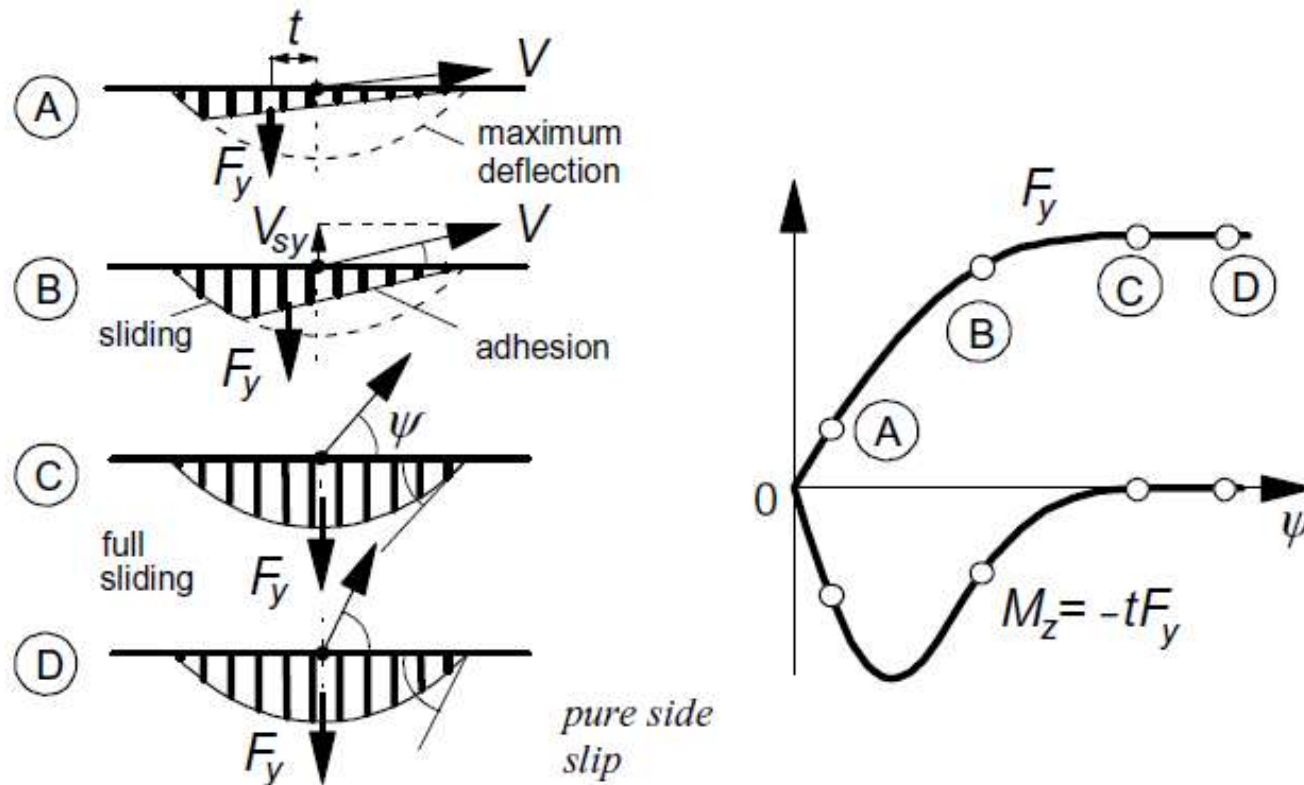
Brush model representing tyre behaviour



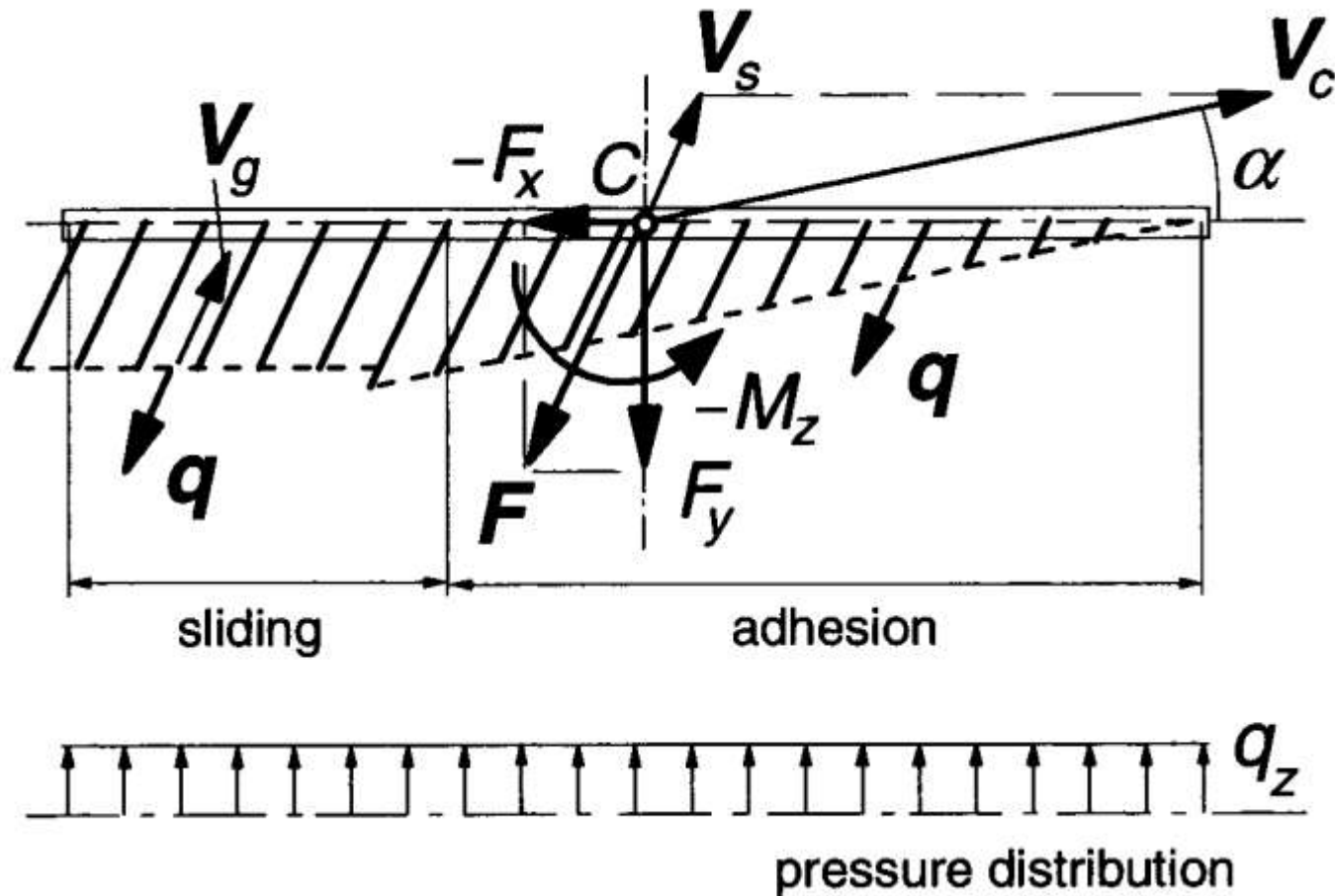
Pacejca Brush Model



Load distribution with brush model



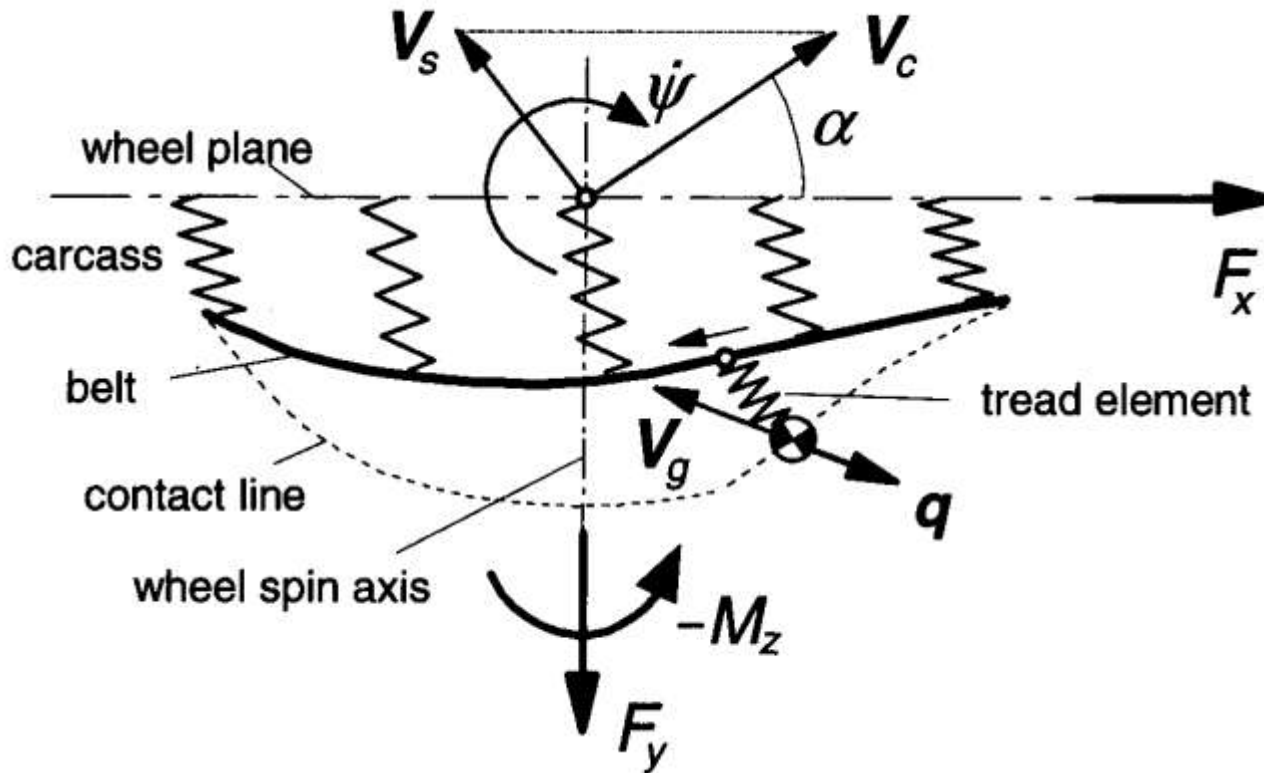
Combined lat and long slip with brush model



4. Complex Physical Models

The final group of mathematical tyre models defined by Pacejka is the use of complex physical models. Complex finite element based models are included in this group

Complex Tyre model



Pacejka's representation of a complex computer simulation tyre model with flexible carcass, arbitrary pressure distribution and friction coefficient functions

Forces acting on a single tread element mass during one passage through the contact length are integrated to obtain the total forces and moments F_x , F_y and M_z