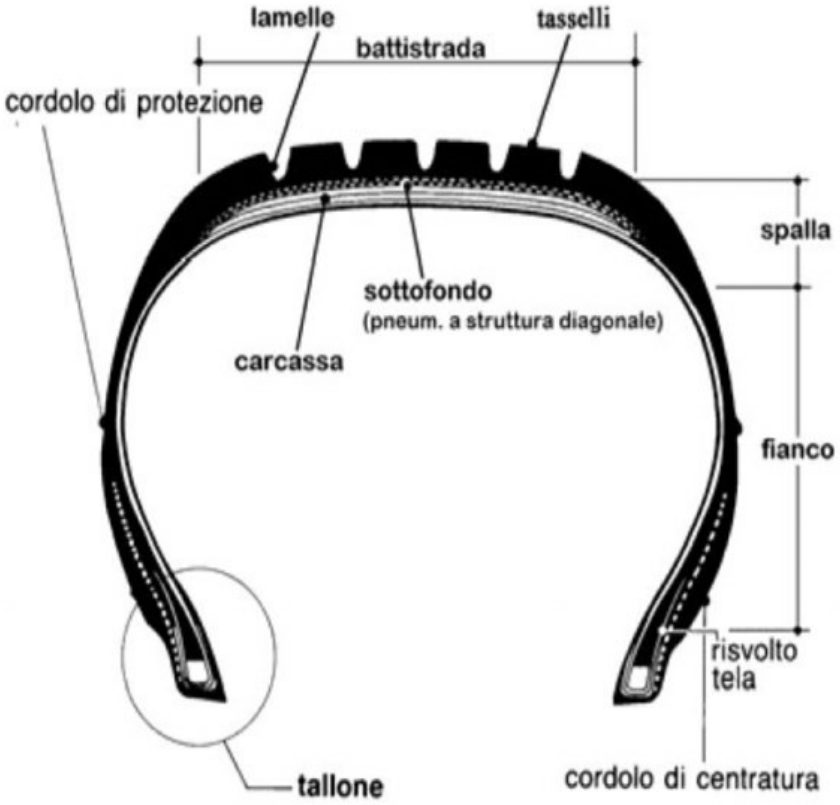
Vehicle dynamics

Lezione n. 7:

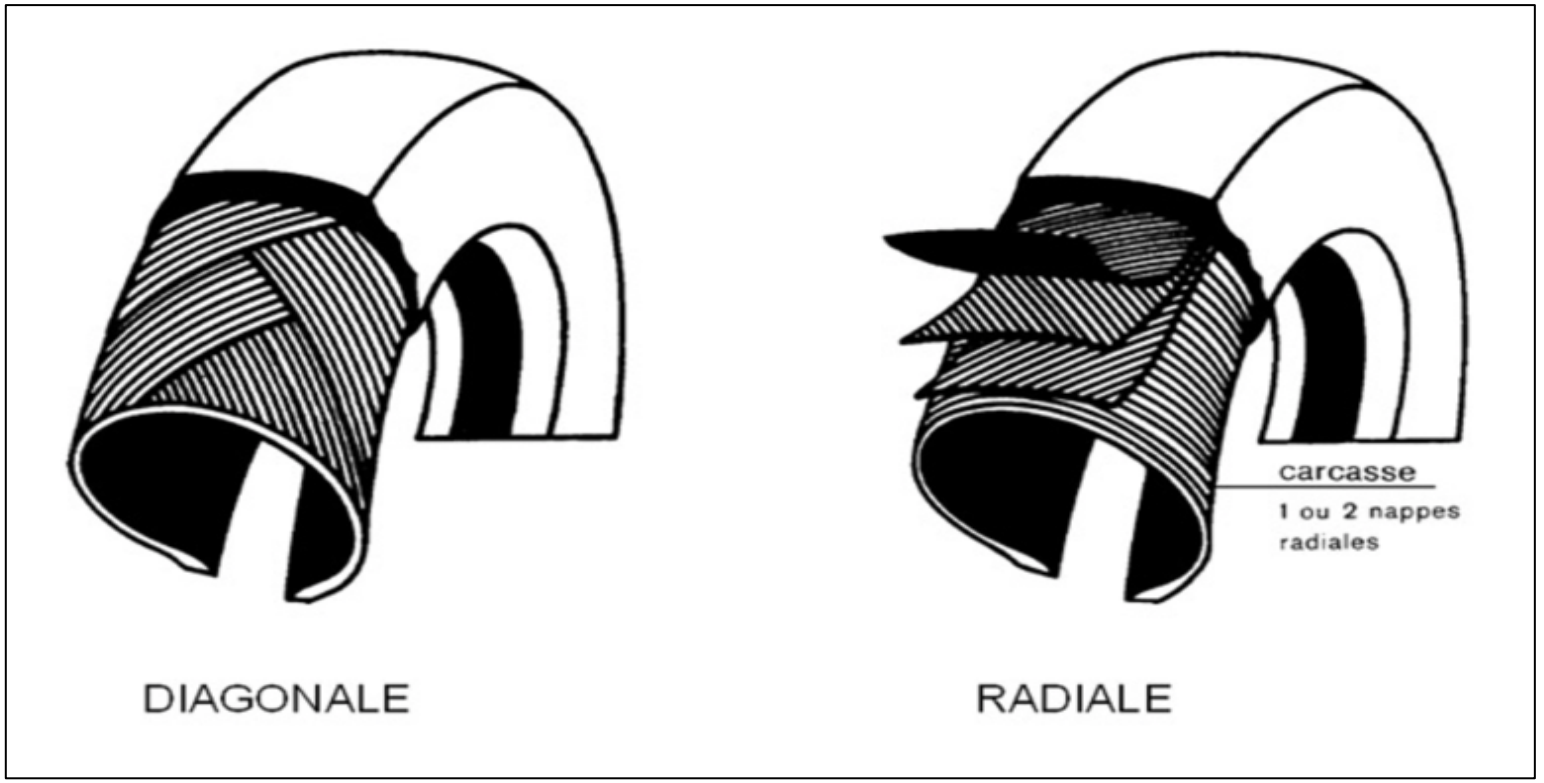
Tire

Structure


lamelle
tasselli
battistrada
cordolo di protezione
spalla
sottofondo
(pneum. a struttura diagonale)
carcassa
fianco
risvolto
tela
tallone
cordolo di centratura

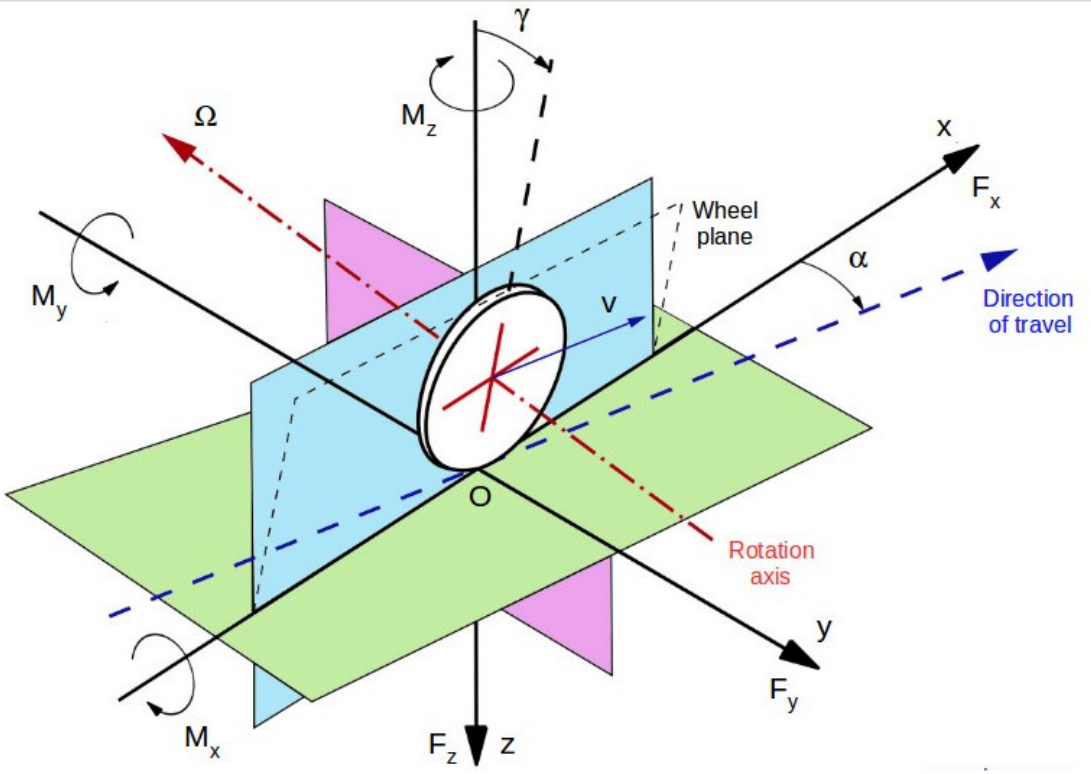

10 Tire Shoulder
9 Sidewall
08 Tread Pattern
07 Nylon Cover
06
Steel Belt
06
05
Carcass
05
04 Inner Liner
03 Rim
02
02
Bead Filler
01
Bead Wire

Types of carcass



Tire characteristics

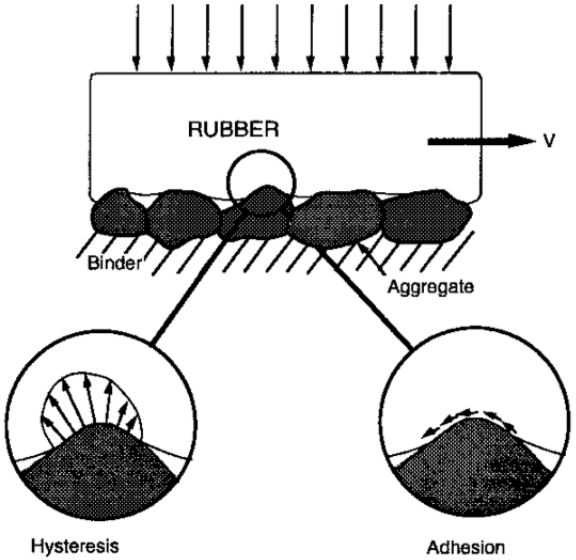
Tire-road interaction

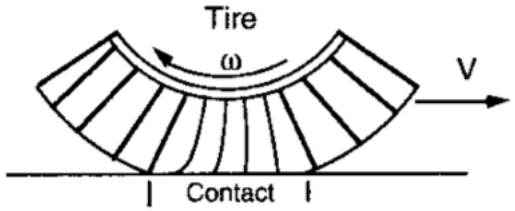


F_x longitudinal force;
F_y lateral force;
F_z vertical load or normal force;

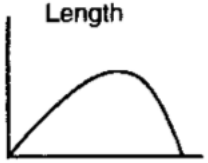
M_x overturning moment;
M_y rolling resistance moment;
M_z self-aligning torque

Longitudinal force

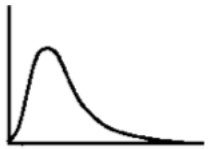




Hysteresis

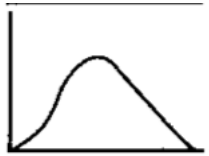


$$Slip = \frac{V - \omega \cdot r}{V}$$



$$\mu = \frac{F_X}{F_Z}$$ Braking coefficient

Adhesion



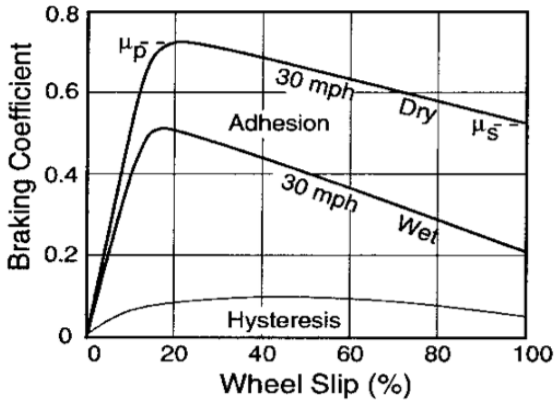
$$\text{Slip}\ (\%) = \left(1 - \frac{r\,\omega}{V}\right) \times 100$$

where:

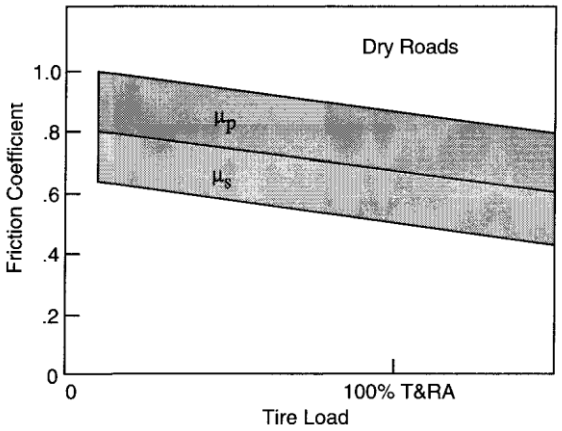
r = Tire effective rolling radius
ω = Wheel angular velocity
V = Forward velocity

Braking coefficient

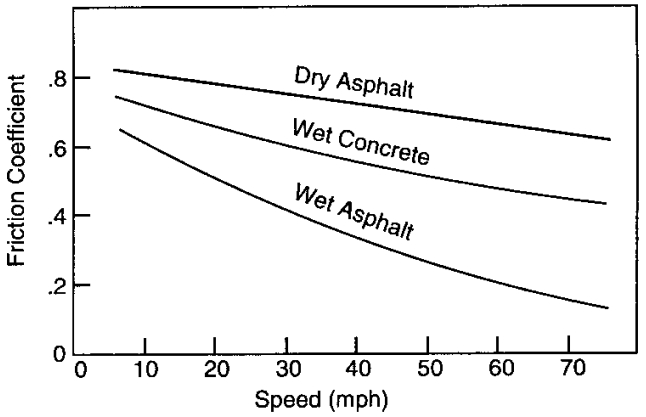
Braking coefficient vs Slip ratio



Braking coefficient vs Load

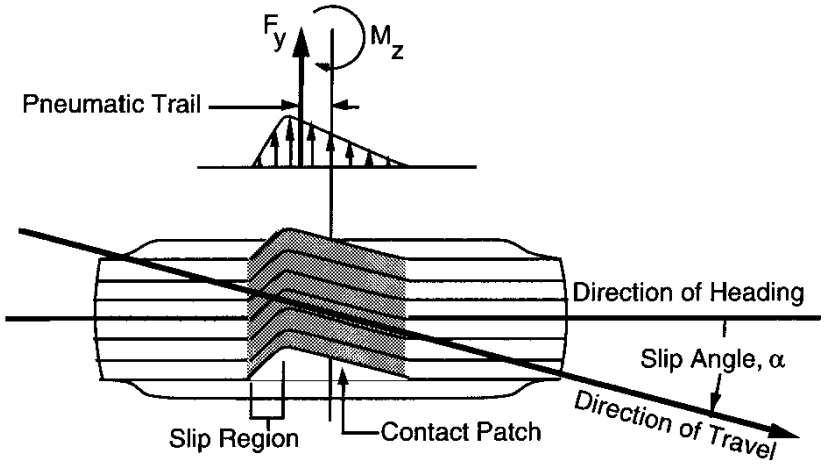


Braking coefficient vs Speed

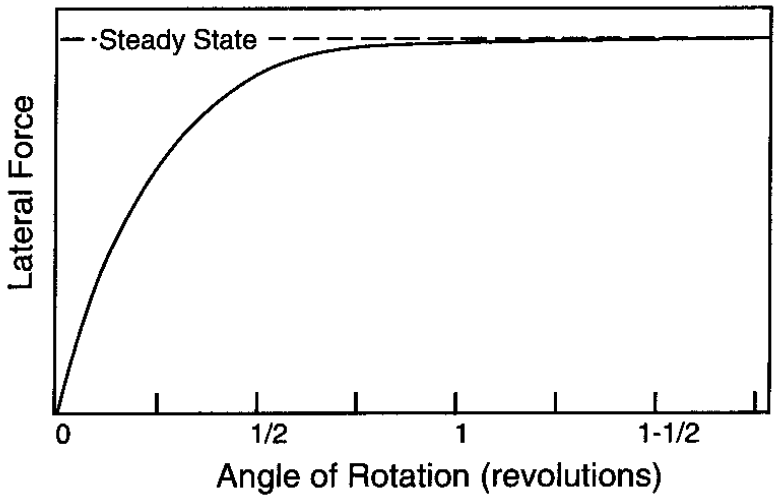


Lateral force

Lateral slip → lateral force

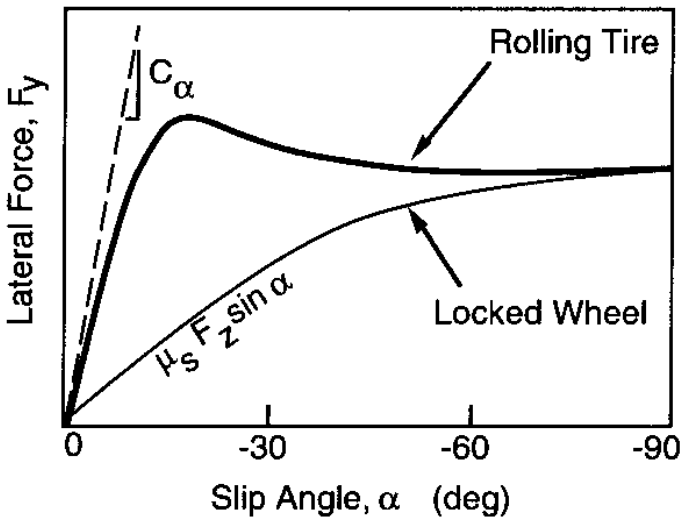


Relaxation lenght

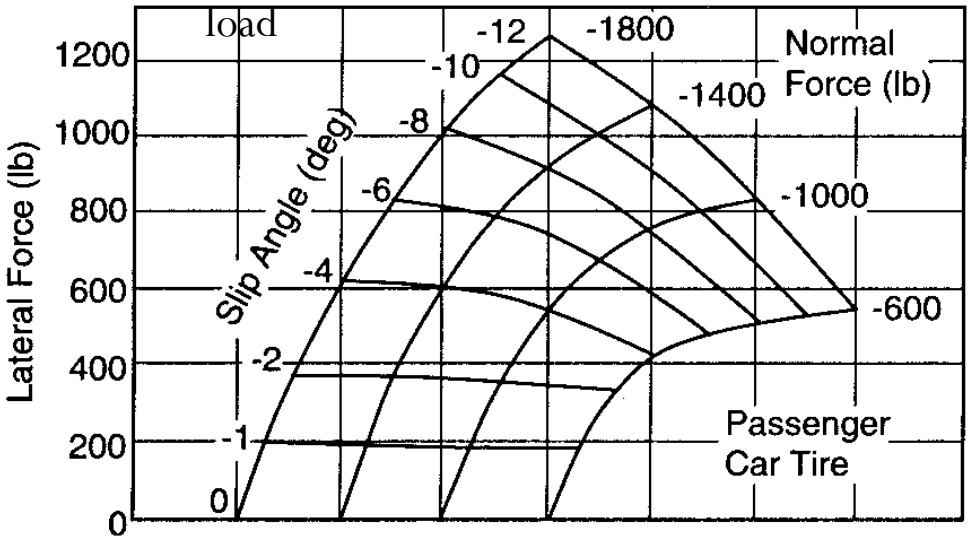


Lateral force

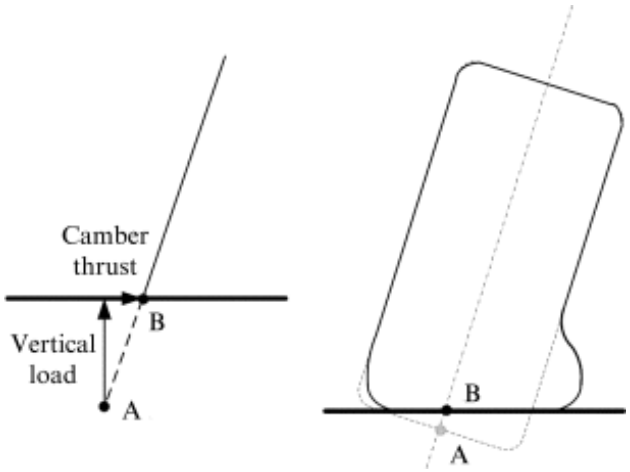
Lateral force vs Slip angle

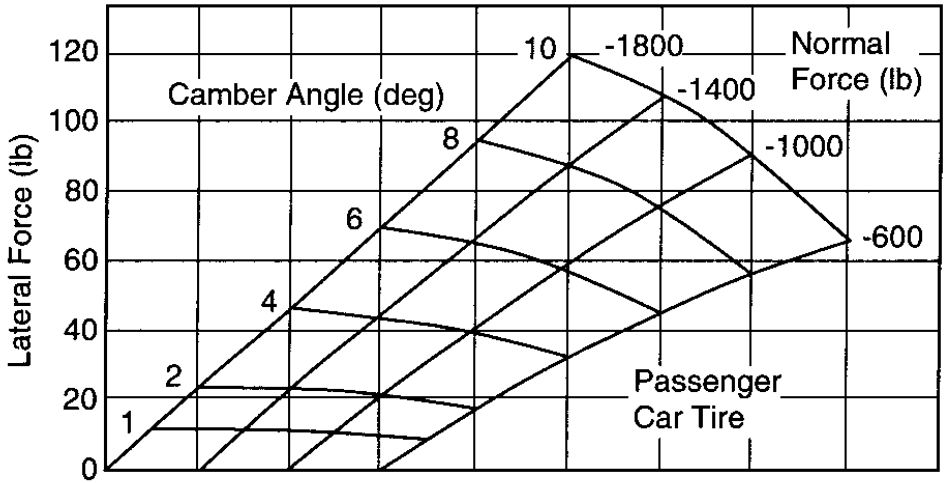


Lateral force vs Slip angle vs normal load

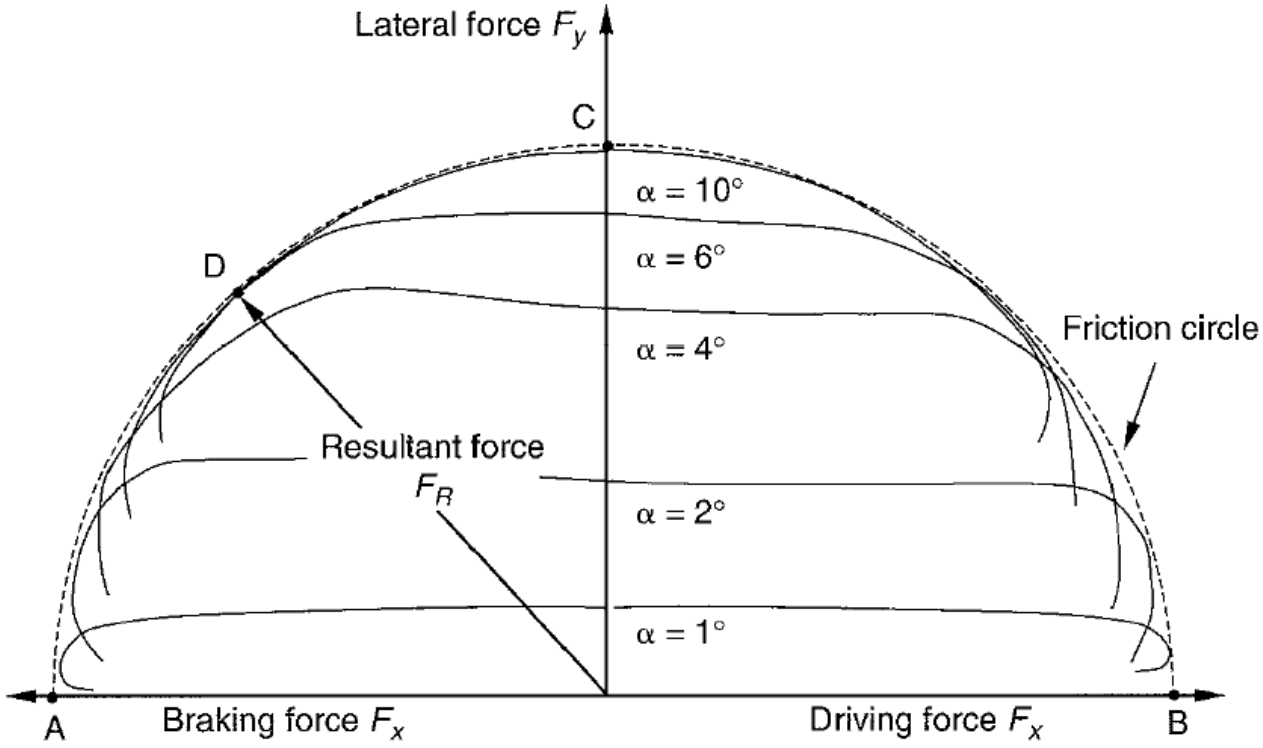


Spinta di camber (camber thrust)





Combined slip

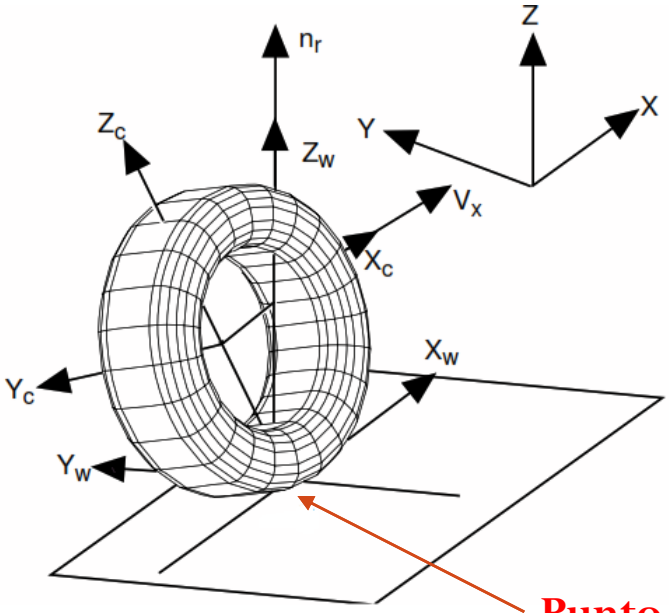


circle of Kamm

I modelli MF-Tyre, MF-MCTyre e SWIFT-Tyre

Modello	Descrizione	Tipo analisi	Input	Output
MF-Tyre	Modello Basato sulla Magic Formula di Pacejka per la modellazione del comportamento stazionario e transitorio dell'interazione pneumatico-strada	Stazionario e Transitorio fino a 8 Hz	slip κ and α Wheel camber γ Vertical force Fz t per analisi transitorio	Fx, Fy Mx, My, Mz In caso di pure o combined slip
MFC-Tyre	MF-tyre ottimizzato per elevati valori di angoli camber (usato per modellazione di veicoli a due ruote o in caso di analisi di roll over)	Stazionario e Transitorio fino a 8 Hz	slip κ and α Wheel camber γ Vertical force Fz t per analisi transitorio	Fx, Fy Mx, My, Mz In caso di pure o combined slip
SWIFT-Tyre	Combina i risultati della Magic Formula di Pacejka con un modello ad anello rigido di pneumatico. (studi di durata, analisi shimmy, ABS, ESP, cornering strade dissestate)	Stazionario e Transitorio 60-100 Hz	slip κ and α Wheel camber γ Vertical force Fz t per analisi transitorio	Fx, Fy Mx, My, Mz In caso di pure o combined slip

Carico normale



Carico Normale

$$F_z = C_z \cdot \dot{\rho} + K_z \cdot \rho$$

Dove ρ: deflessione

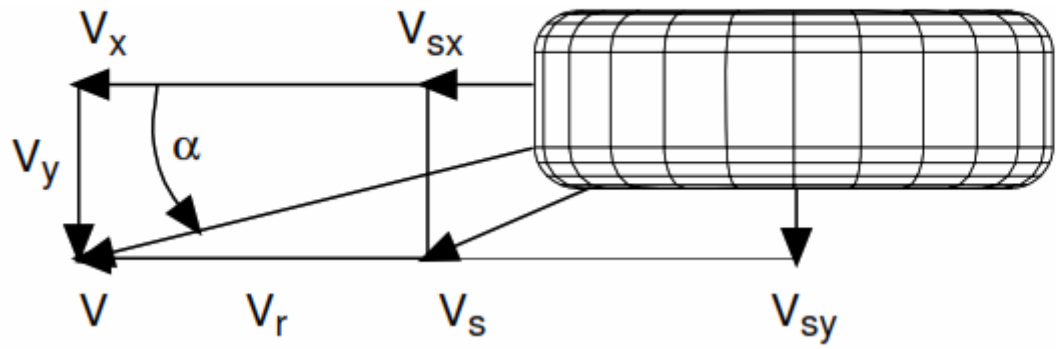
ρ̇: velocità di deflessione

Kz: rigidezza verticale

Cz: smorzamento verticale

Longitudinal slip

Slip Quantities at Combined Cornering and Braking/Traction



Velocità di slip longitudinale:

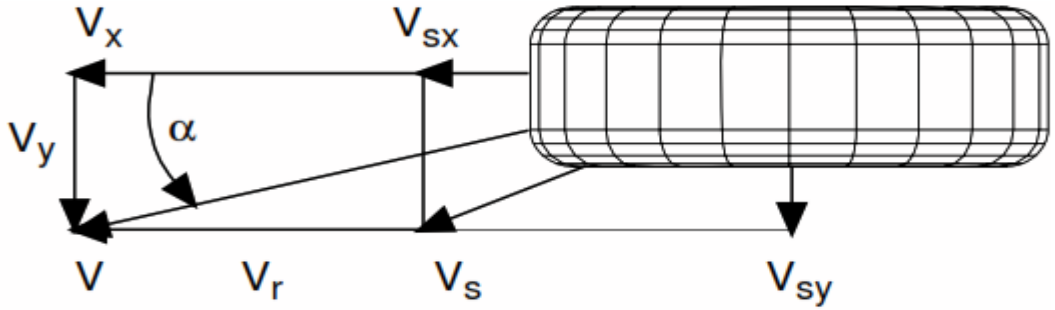
$$V_{sx} = V_x - \Omega R_e$$

Slip longitudinale

$$\kappa = -\frac{V_{sx}}{V_x}$$

Lateral slip

Slip Quantities at Combined Cornering and Braking/Traction



Velocità di slip laterale:

$$V_{sy} = V_y$$

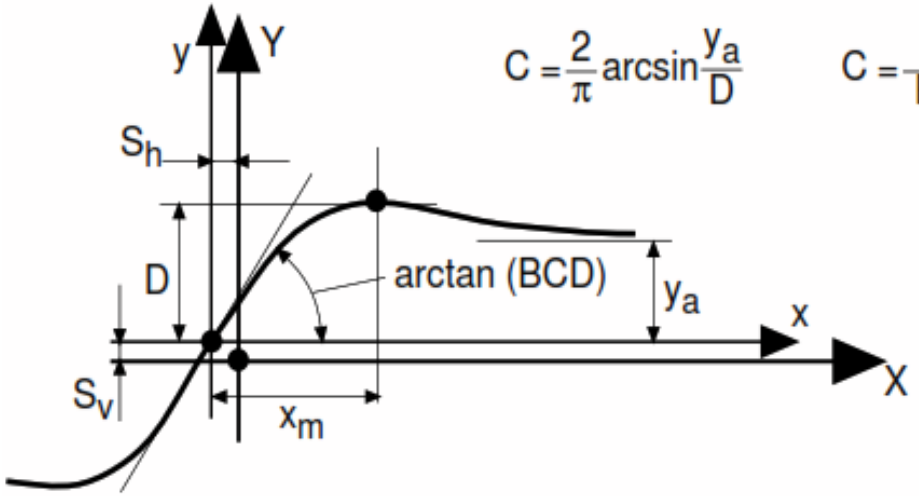
Slip laterale

$$\tan\alpha = \frac{V_{sy}}{|V_x|}$$

Magic Formula (MF-Tyre): braking/cornering

Longitudinal or lateral force

$$Y(x) = D\sin[C\arctan\{Bx - E(Bx - \arctan(Bx))\}]$$



$$C = \frac{2}{\pi}\arcsin\frac{y_a}{D} \qquad C = \frac{Bx_m\text{-}\tan(\pi/2C)}{Bx_m\text{-}\arctan(Bx_m)} \quad (C>1)$$

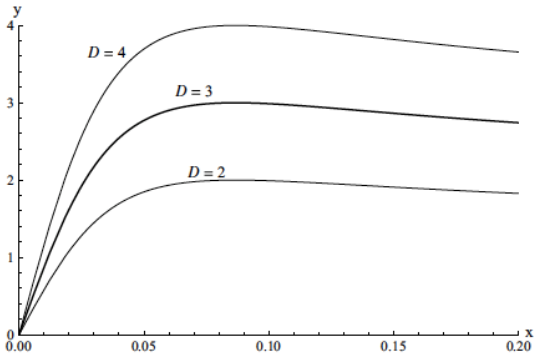
Magic Formula (MF-Tyre): braking/cornering

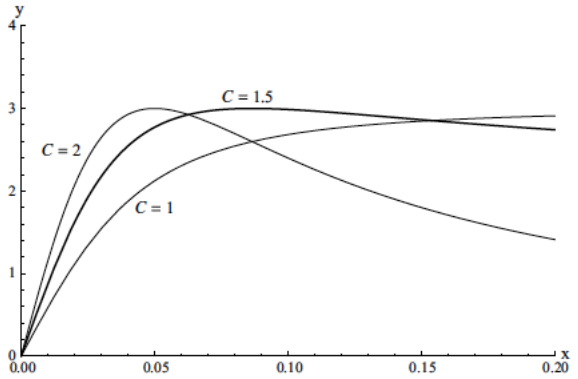
$$Y(x) = D\sin[C\arctan\{Bx - E(Bx - \arctan(Bx))\}]$$

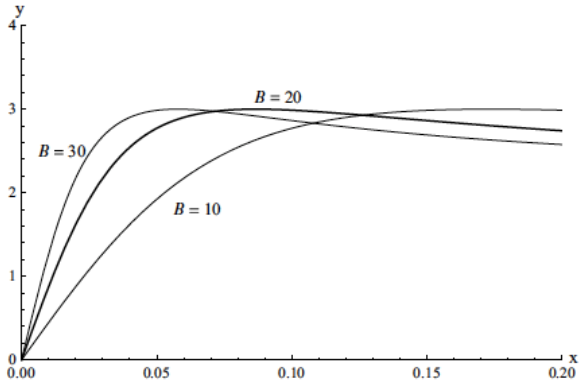
Experimental data

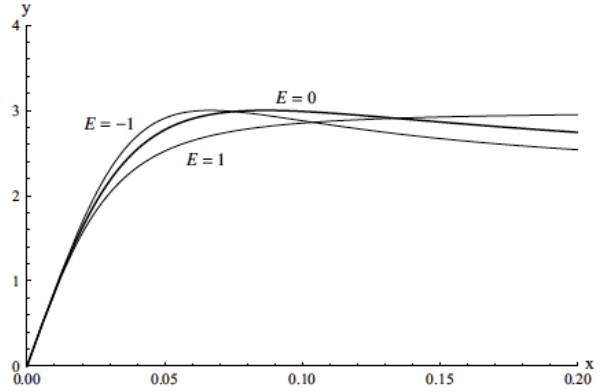
Curve fitting

B	stiffness factor
C	shape factor
D	peak value
E	curvature factor









Magic Formula (MF-Tyre): I/O

INPUT		
DESCRIZIONE	**SIMBOLO**	**UNITÀ DI MISURA**
Slip longitudinale	K	-
Slip laterale	α	-
Camber	γ	rad
Forza verticale	Fz	N

OUTPUT		
DESCRIZIONE	**SIMBOLO**	**UNITÀ DI MISURA**
Forza longitudinale	Fx	N
Forza laterale	Fy	N
Coppia di ribaltamento	Mx	Nm
Resistenza al rotolamento	My	Nm
Coppia di allinamento	Mz	Nm

Peso computazionale ed applicazioni