

**Universidade Federal do Paraná**  
**Setor de Tecnologia**  
**Departamento de Engenharia Mecânica**

# TMEC078-FUNDAMENTOS DE DINÂMICA VEICULAR

## 5-Pneus e balanço

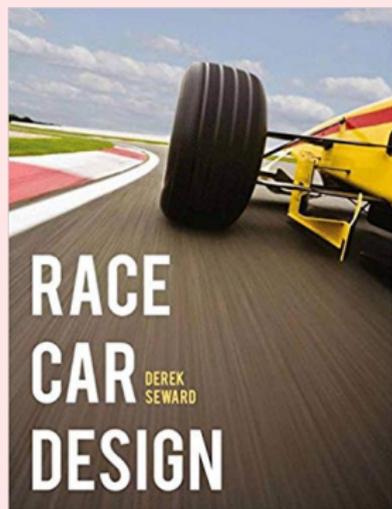
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# Apresentação



Este documento apresenta as figuras do Capítulo 5 do livro de Derek Seward (SEWARD, 2014).

# Sumário

- 1 Introdução
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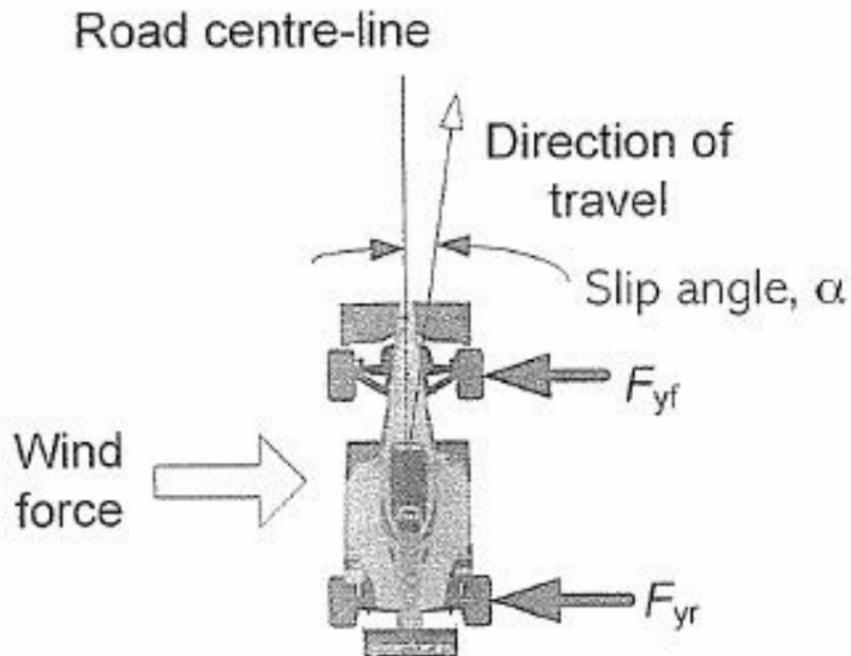


Figura: 5.1a: Carro deslocado para fora do curso por vento lateral.

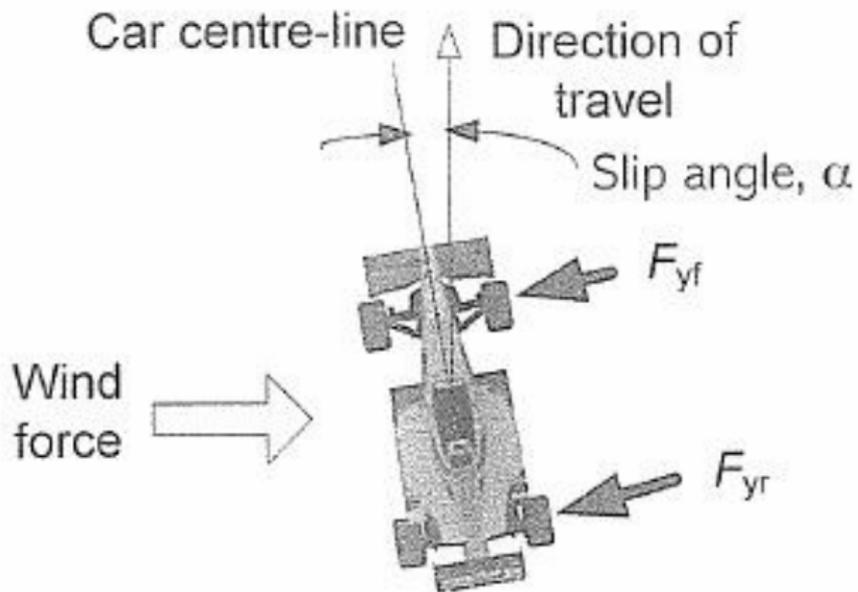


Figura: 5.1b: Direção corrigida: carro neutro.

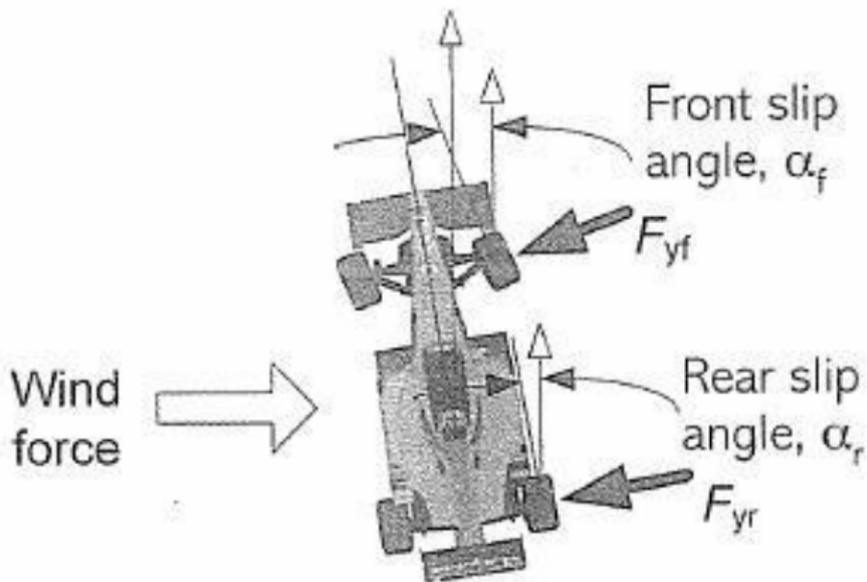


Figura: 5.1c: Direção corrigida: carro understeer.

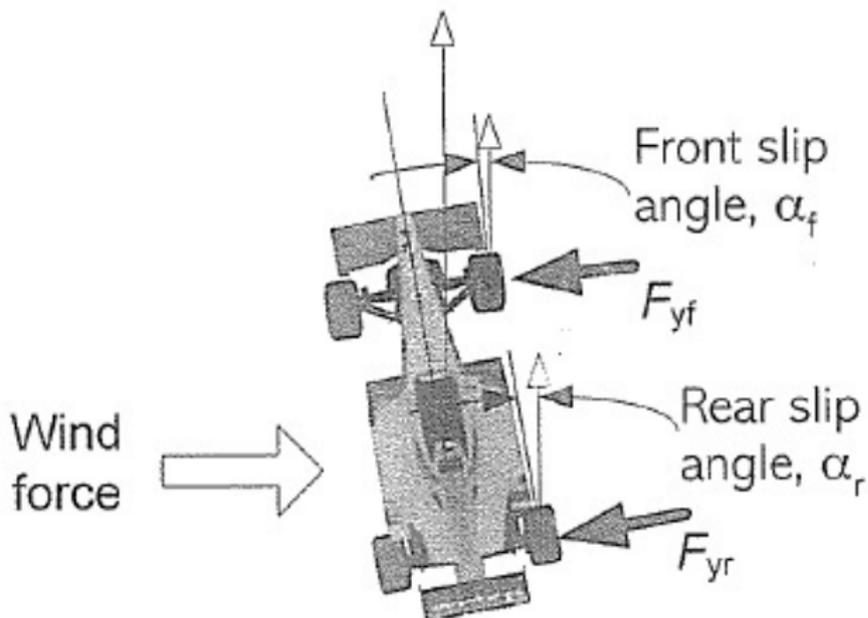


Figura: 5.1d: Direção corrigida: carro oversteer.

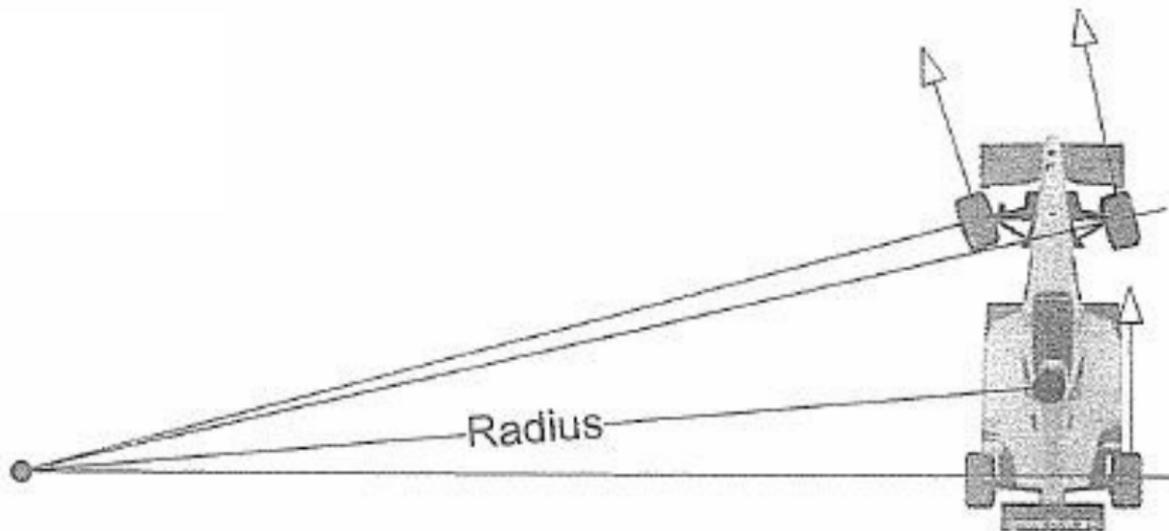


Figura: 5.2a: Carro lento com forças laterais desprezíveis.

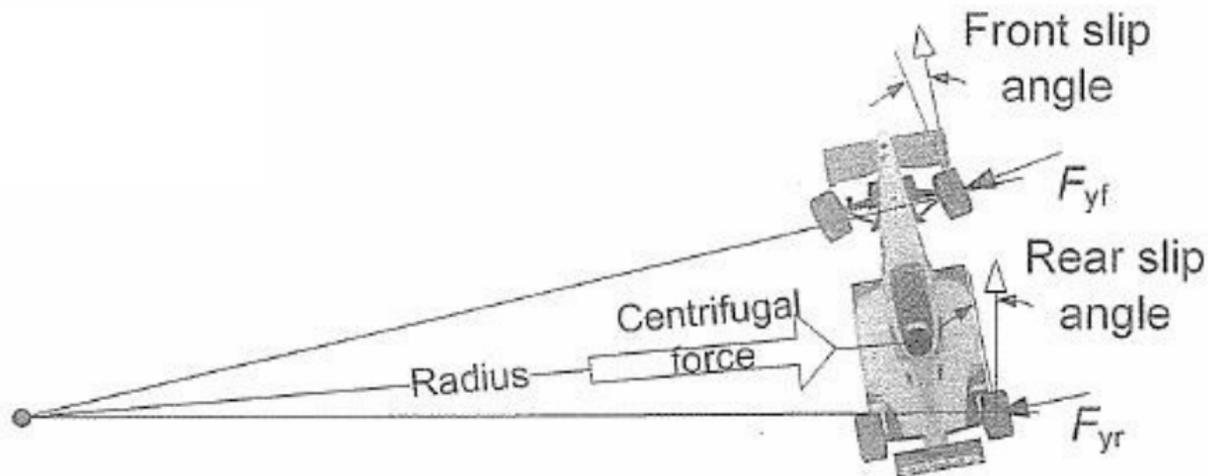


Figura: 5.2b: Carro veloz com forças laterais elevadas.

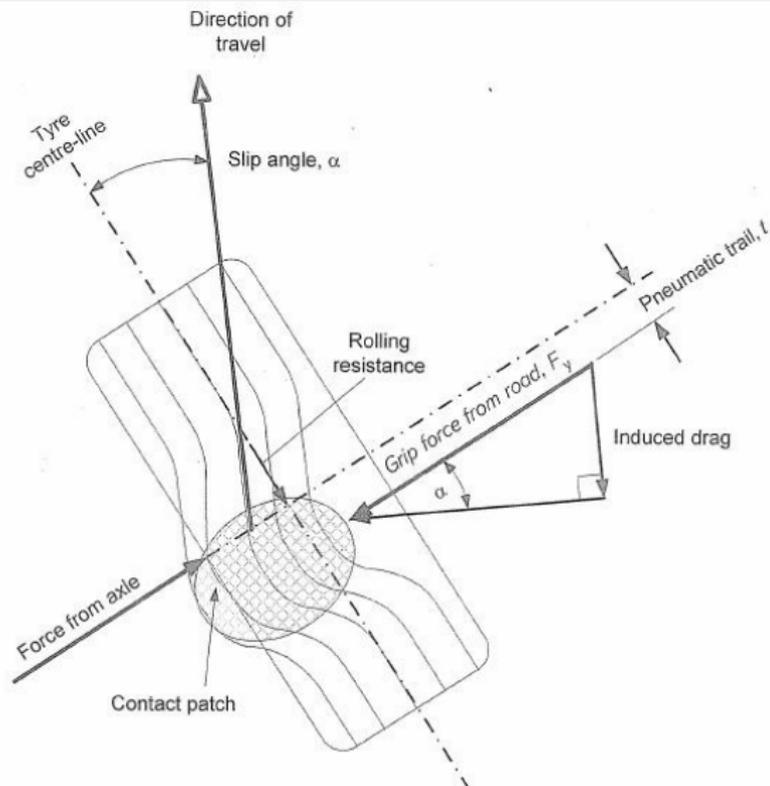


Figura: 5.3: Forças no pneu em curva.

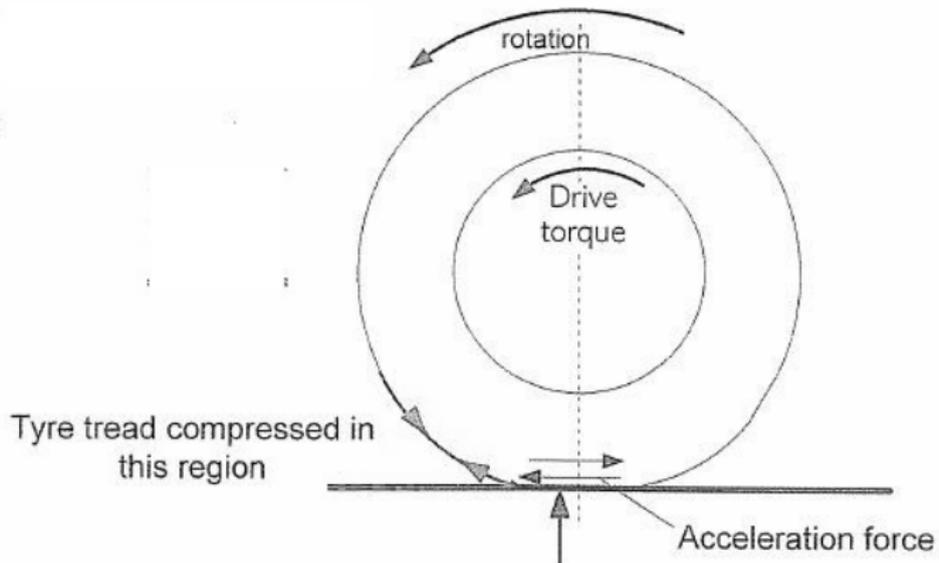


Figura: 5.4: Pneu sob aceleração.

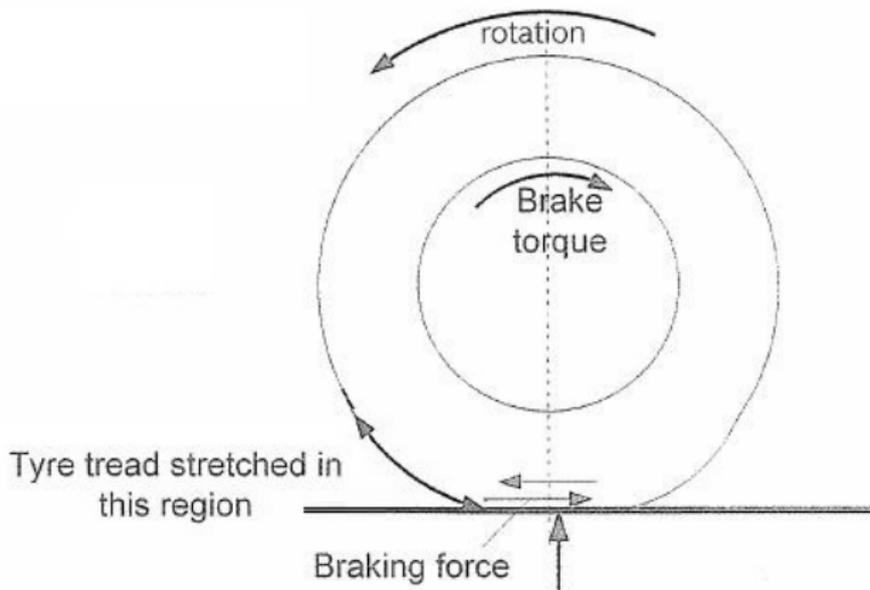


Figura: 5.5: Pneu sob frenagem.

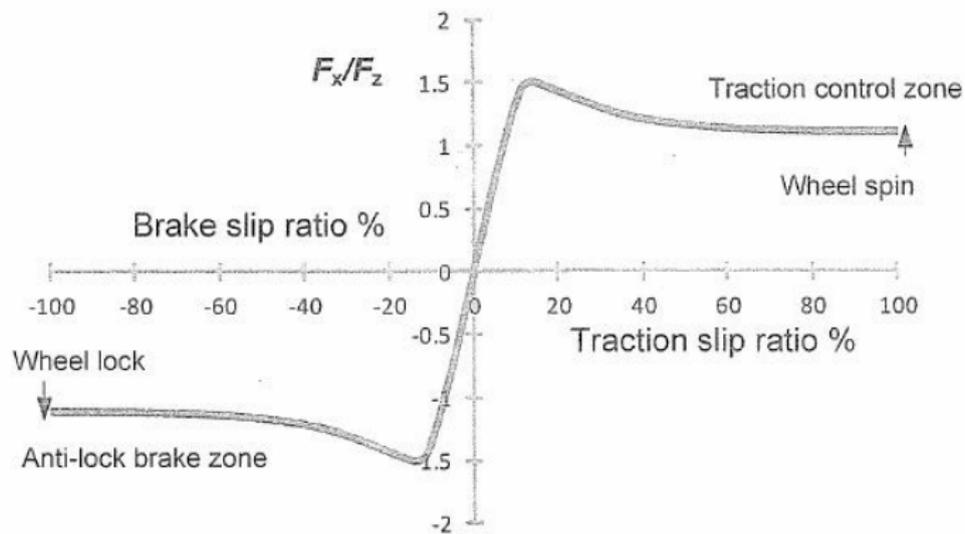


Figura: 5.6: Aderência longitudinal x razão de escorregamento.

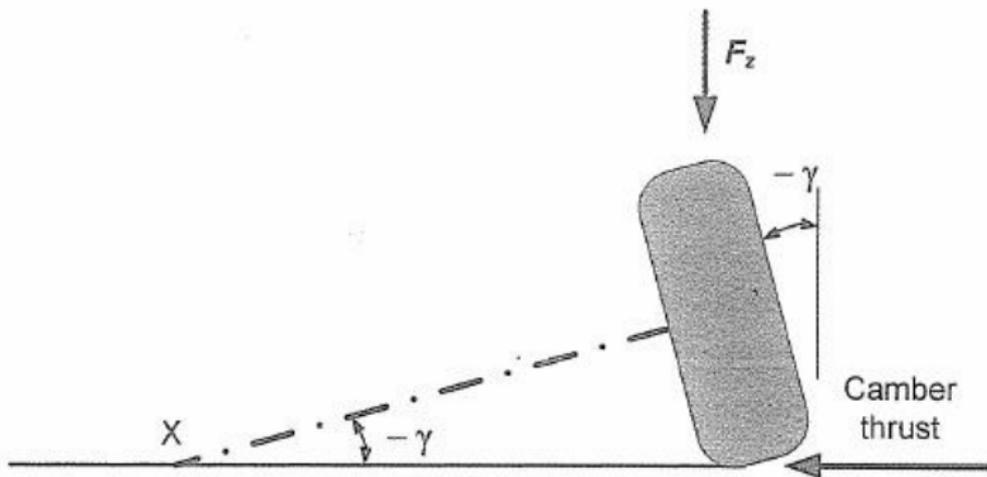


Figura: 5.7: Cambagem e *camber thrust*.

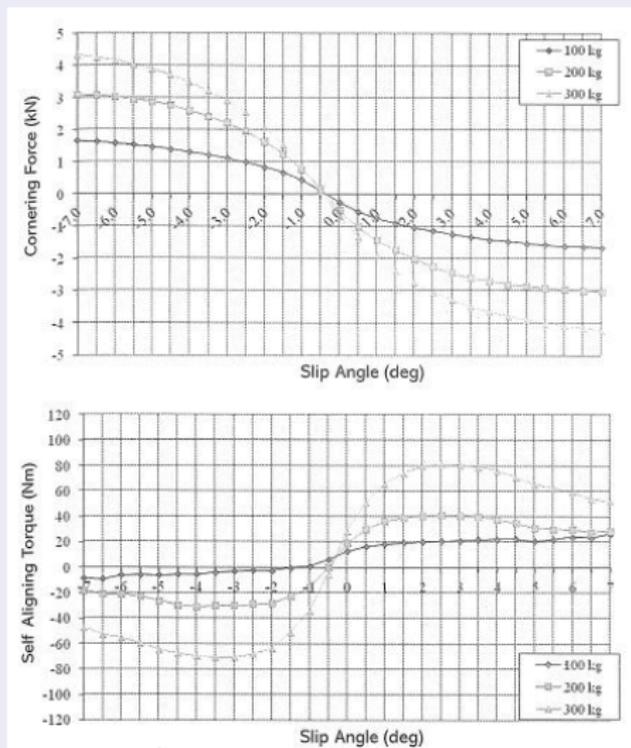
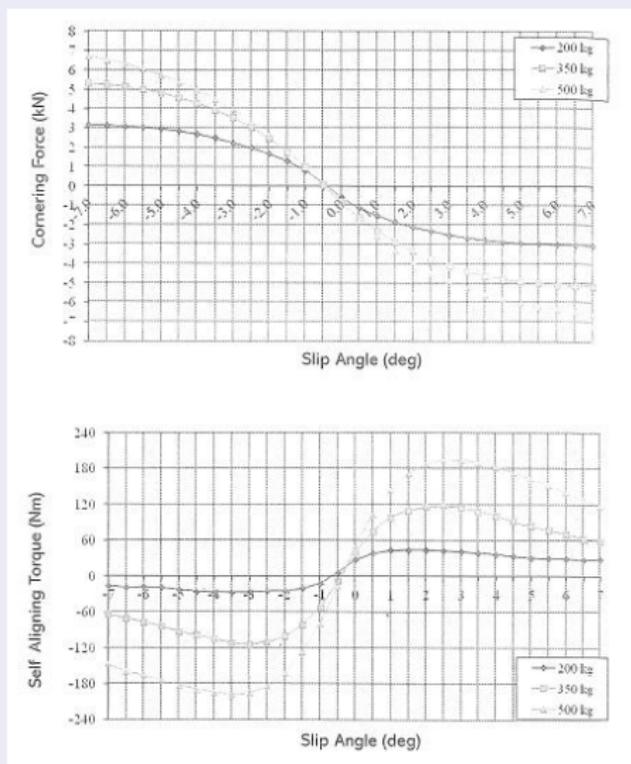


Figura: 5.8a: Dados de teste de um pneu dianteiro de F3: 180/500R13; 0° camber; 1.7 bar



**Figura:** 5.8b: Dados de teste de um pneu traseiro de F3: 250/570R13; 0° camber; 1.7 bar



**Table 5.1** Pacejka coefficients – Avon British F3 Tyres

	Front	Rear	Description
$F_{Z0}$ =	2444	3850	Nominal load (N)
$P_{Cr1}$ =	0.324013	0.558238	Shape factor
$P_{Dr1}$ =	-3.674945	-2.23053	Lateral friction, $\mu_y$
$P_{Dr2}$ =	0.285134	0.090785	Variation of friction with load
$P_{Dr3}$ =	-2.494252	-5.71836	Variation of friction with camber squared
$P_{Ev1}$ =	-0.078785	-0.40009	Lateral curvature at $F_{Z0}$
$P_{Ev2}$ =	0.245086	0.569694	Variation of curvature with load
$P_{Ev3}$ =	-0.382274	-0.26276	Zero order camber dependency of curvature
$P_{Ev4}$ =	-6.25570332	-29.3487	Variation of curvature with camber
$P_{Kv1}$ =	-41.7228113	-28.2448	Maximum value of stiffness $K_y/F_{Z0}$
$P_{Kv2}$ =	2.11293838	1.331304	Normalised load at which $K_y$ reaches max. value
$P_{Kv3}$ =	0.150080764	0.255683	Variation of $K_y/F_{Z0}$ with camber
$P_{Hy1}$ =	0.00711	0.00847	Horizontal shift $S_{Hy}$ at $F_{Z0}$
$P_{Hy2}$ =	-0.000509	0.000594	Variation of $S_{Hy}$ with load
$P_{Hy3}$ =	0.049069131	0.042	Variation of $S_{Hy}$ with camber
$P_{Vy1}$ =	-0.00734	0.0262	Vertical shift $S_{Vy}$ at $F_{Z0}$
$P_{Vy2}$ =	-0.0778	-0.0791	Variation of $S_{Vy}$ with load
$P_{Vy3}$ =	-0.0641	-0.08552	Variation of $S_{Vy}$ with camber
$P_{Vy4}$ =	-0.6978041	-0.44481	Variation of $S_{Vy}$ with camber and load

**Figura: Tab. 5-1: Coeficientes de Pacejka - Pneus Avon British F3**



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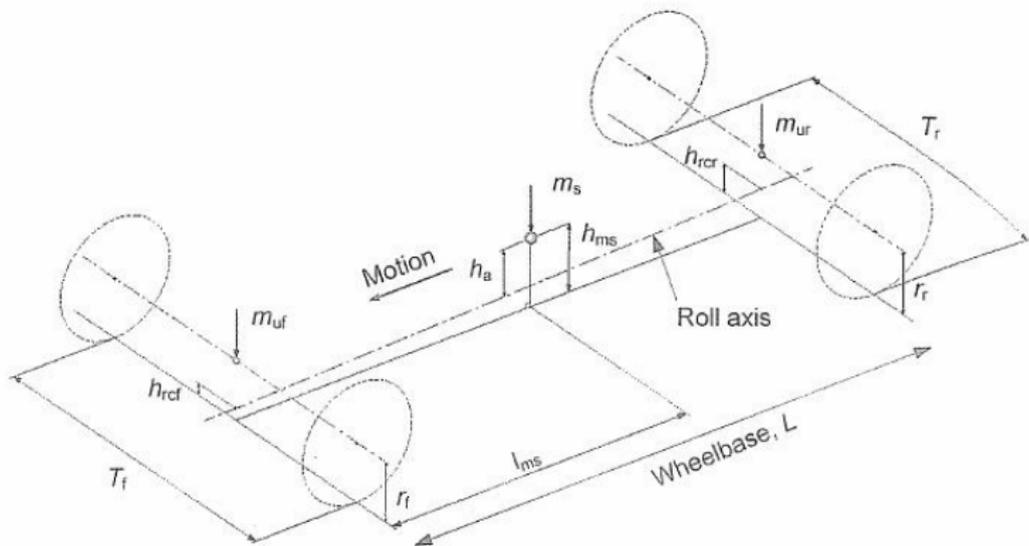


Figura: 5.9: Geometria da transferência de carga lateral.

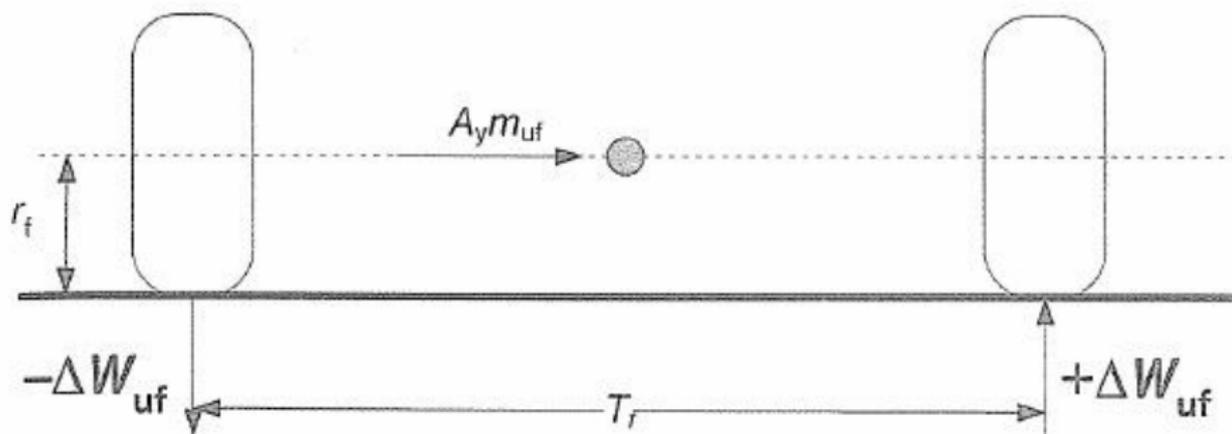


Figura: 5.10: Transferência de carga lateral da massa não suspensa dianteira.

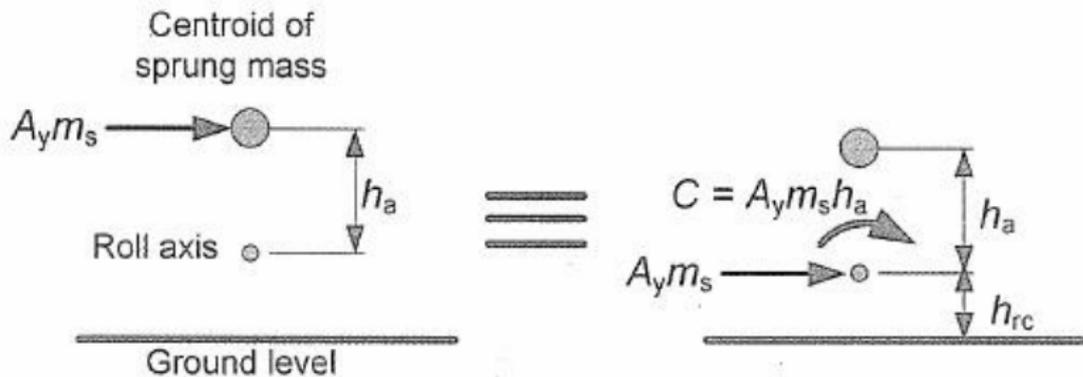
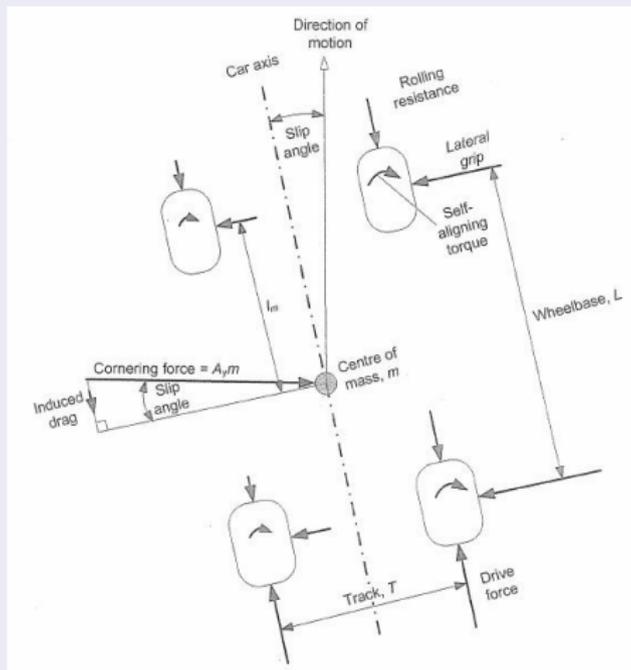


Figura: 5.11: Transferência de carga lateral da massa suspensa.



**Figura:** 5.12: Fatores que afetam o understeer/oversteer - **carro neutro.**

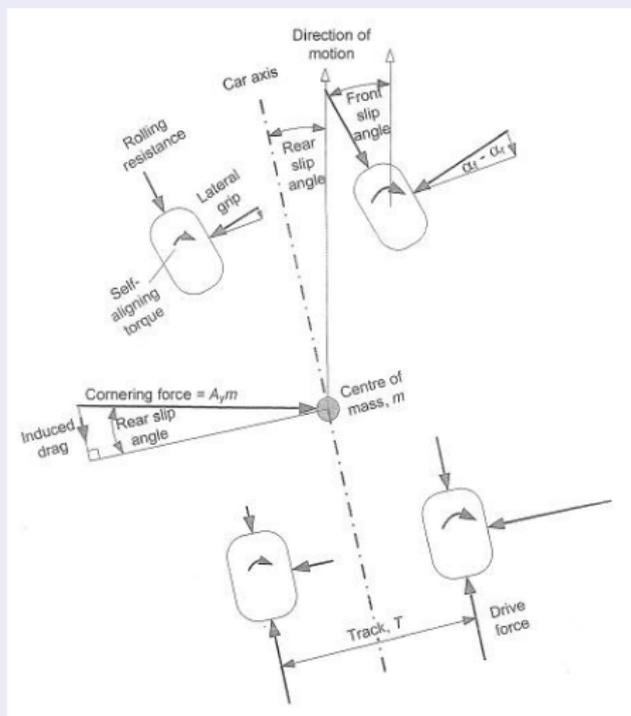


Figura: 5.13: Fatores que afetam o understeer/oversteer  
- carro understeer

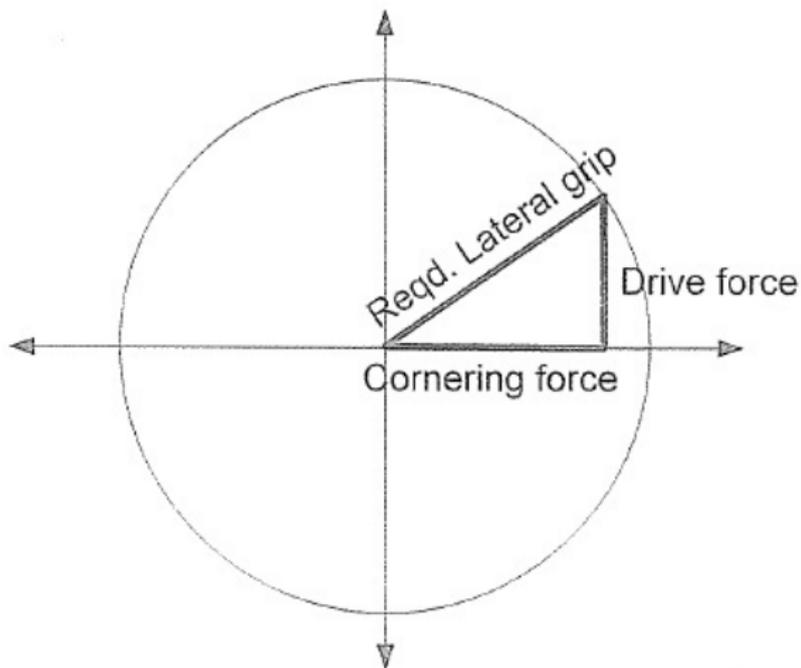


Figura: 5.14: Compensação para força de tração.

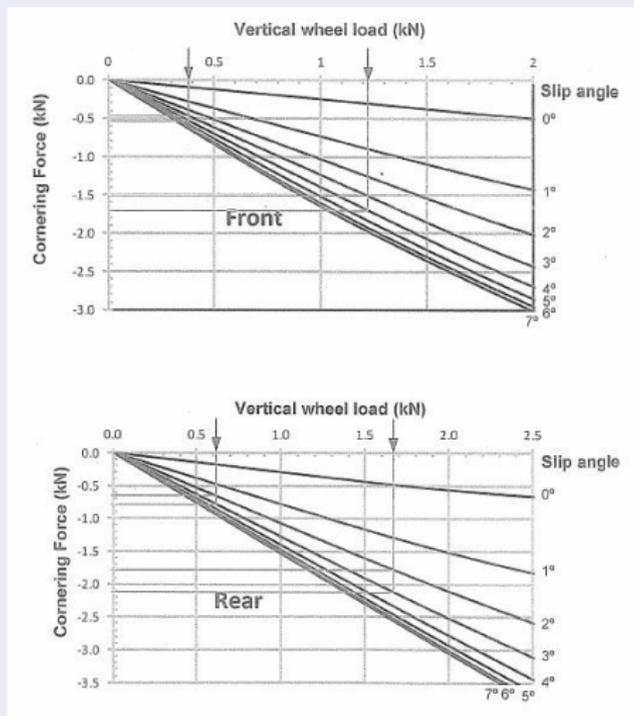


Figura: 5.15: Dados de teste de pneus. Redesenho das Figuras 5.8a e 5.8b

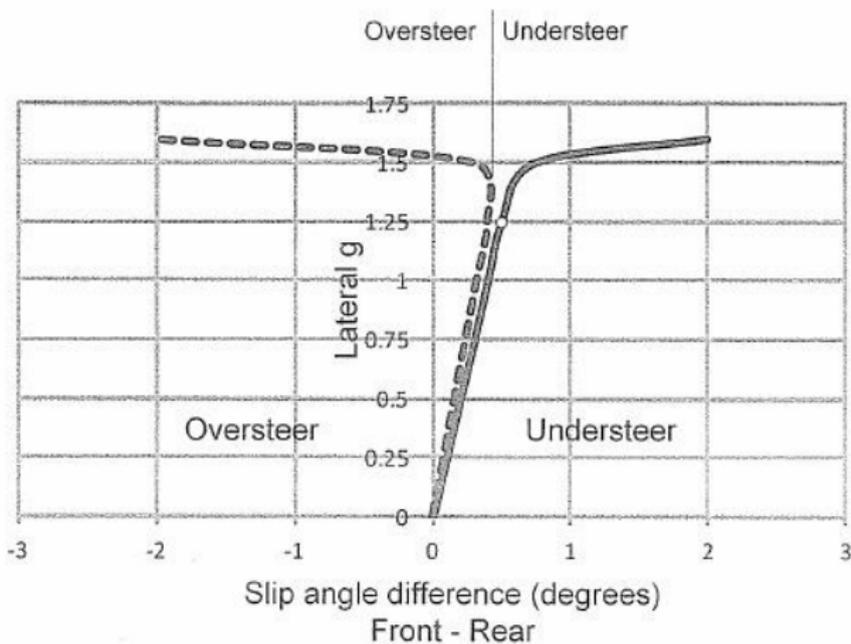
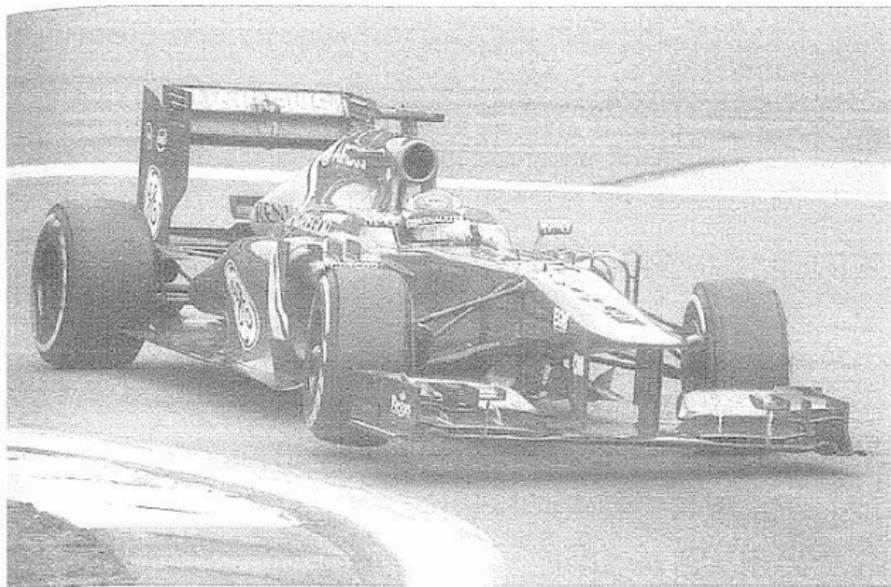


Figura: 5.16: Curvas de dirigibilidade.



**Figura:** 5-17: Charles Pic elevando a roda interna no GP da Alemanha de 2013.

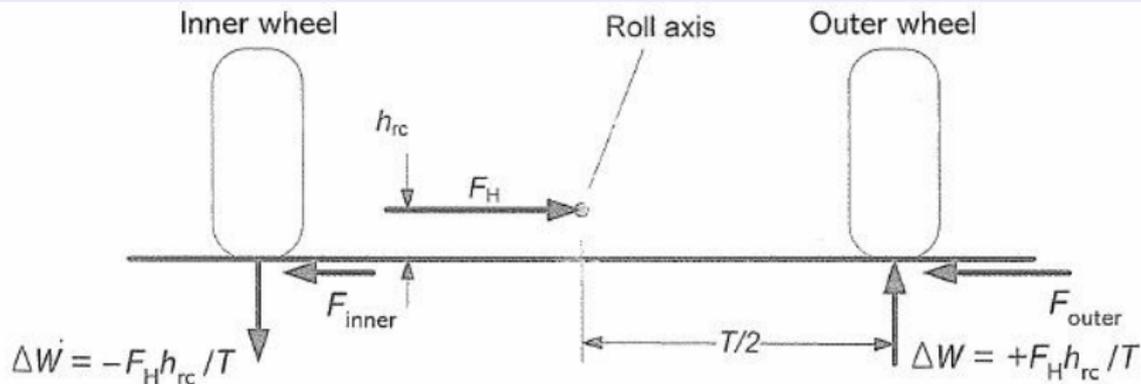


Figura: 5.18: Calculando *jacking* numa curva.

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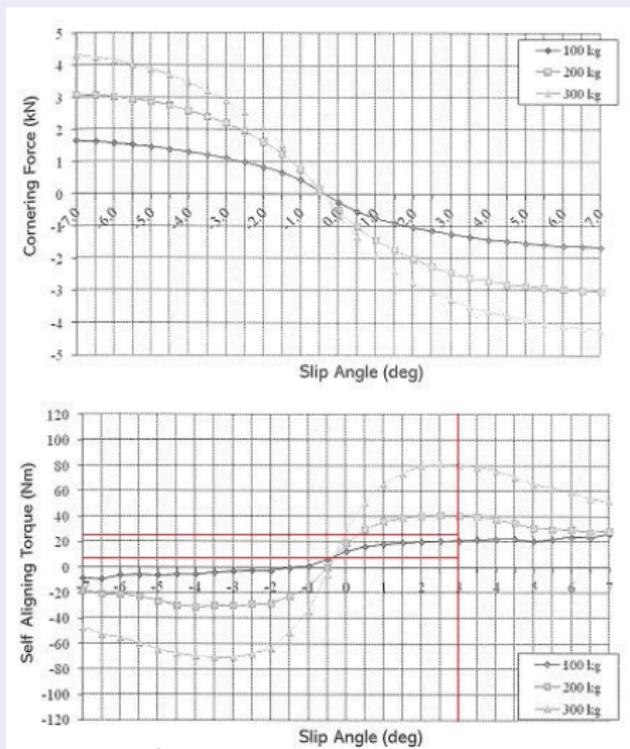


Figura: 5.8a: Dados de teste de um pneu dianteiro de F3: 180/500R13; 0° camber; 1.7 bar

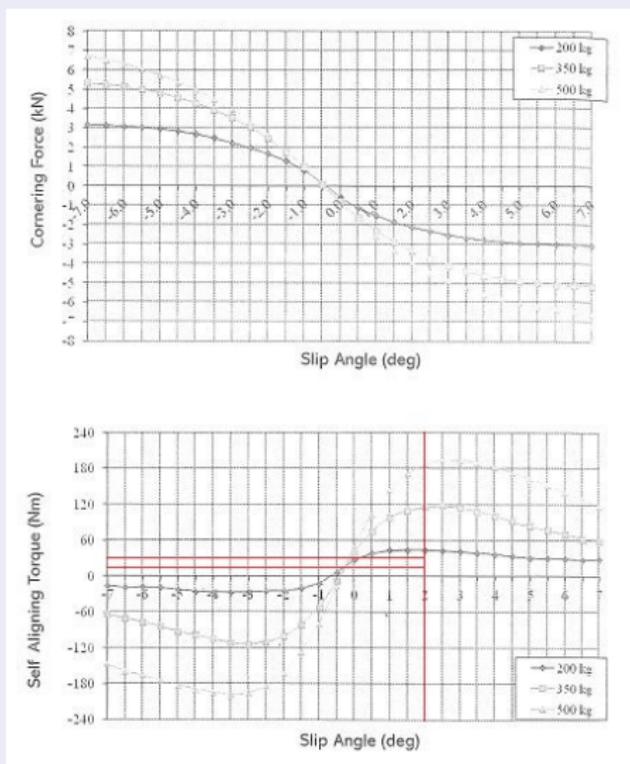


Figura: 5.8b: Dados de teste de um pneu traseiro de F3: 250/570R13; 0° camber; 1.7 bar

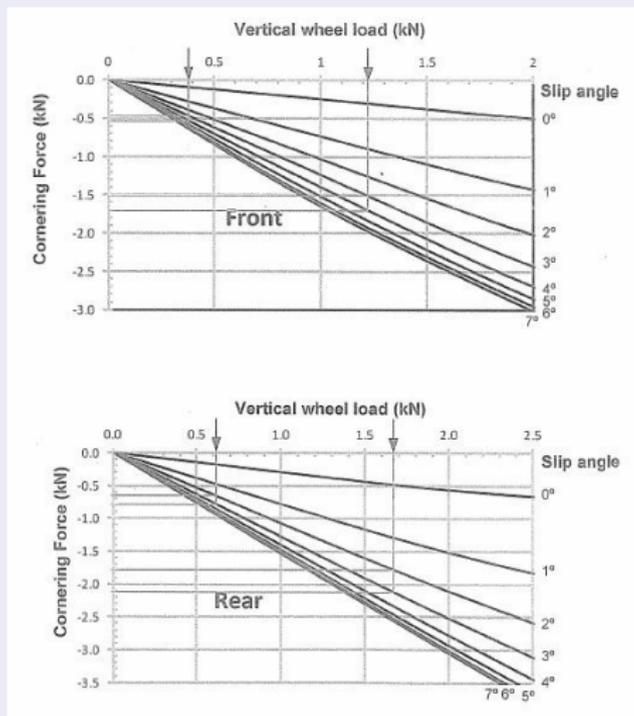


Figura: 5.15: Dados de teste de pneu: redesenhado a partir das Figuras 5-8a e 5-8b

Lateral Force	Front 180/550	Front 180/550	Rear 250/570	Rear 250/570
PCy1	0.324013	0.324013	0.558238	0.558238
PDy1	-3.674945	-3.674945	-2.23053	-2.23053
PDy2	0.285134	0.285134	0.090785	0.090785
PDy3	-2.494252	-2.494252	-5.71836	-5.71836
PEy1	-0.078785	-0.078785	-0.40009	-0.40009
PEy2	0.245086	0.245086	0.569694	0.569694
PEy3	-0.382274	-0.382274	-0.26276	-0.26276
PEy4	-6.25570332	-6.25570332	-29.3487	-29.3487
PKy1	-41.7228113	-41.7228113	-28.2448	-28.2448
PKy2	2.11293838	2.11293838	1.331304	1.331304
PKy3	0.150080764	0.150080764	0.255683	0.255683
PHy1	0.00711	0.00711	0.00847	0.00847
PHy2	-0.000509	-0.000509	0.000594	0.000594
PHy3	0.049069131	0.049069131	0.042	0.042
PVy1	0.00734	0.00734	0.0262	0.0262
PVy2	-0.0778	-0.0778	-0.0791	-0.0791
PVy3	-0.0641	-0.0641	-0.08552	-0.08552
PVy4	-0.6978041	-0.6978041	-0.44481	-0.44481
$\lambda_{Fz0}$	1	1	1	1
$\lambda_{iy}$	1	1	1	1
$\lambda_{Ky\alpha}$	1	1	1	1
$\lambda_{Cy}$	1	1	1	1
$\lambda_{Ey}$	1	1	1	1
$\lambda_{Hy}$	1	1	1	1
$\lambda_{Vy}$	1	1	1	1
$\lambda_{Ty}$	1	1	1	1
$\lambda_{Ky\gamma}$	1	1	1	1

Figura: Tab. 5.2: Planilha de Pacejka - Pneus Avon

Wheel load (N)	381.0	1233.0	628.0	1682.00
Downforce (N)	0	0	0	0
Fz - normal force (N)	381.0	1233.0	628.0	1682.0
Dfz	-0.84408583	-0.49542738	-0.83687824	-0.563103833
Fz0 - nominal load	2443.652224	2443.652224	3849.885	3849.885
$\alpha$ - slip angle (deg)	2.85	2.85	2.25	2.25
$\alpha$ - slip angle (rad)	0.049741884	0.049741884	0.039269908	0.039269908
$\gamma$ - camber (deg)	0	0	0	0
$\gamma$ - camber (rad)	0	0	0	0
SHy	0.00753964	0.007362173	0.007972894	0.006135516
SHy	27.81676346	56.57528065	58.02535942	118.0312252
ay	0.057281523	0.057104056	0.047242802	0.04165424
yy	0	0	0	0
Cy	0.324013	0.324013	0.558238	0.8238
my	-3.91562257	-3.81620819	-2.30650599	-2.28121381
Dy	-1491.8522	-4705.3847	-1448.48576	-3647.72624
Ey	-0.39485848	-0.27674137	-1.10725681	-0.91480711
Kyx	-14965.2297	-46067.4414	-26253.0203	-64412.3134
By	30.95958658	30.21596863	32.46726068	30.0473126
Fy0 (N)	-500.91942	-1569.84708	-797.813558	-2048.64262
Normalised Fy	-1.31	-1.27	-1.27	-1.22
Sum		-2071		-2847

Figura: Tab. 5.2b: Planilha de Paceyka - Pneus Avon

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# Referências I

 SEWARD, D. *Race Car Design*. Suffolk, Inglaterra: Palgrave, 2014. ISBN 1137030143.

