

2.2 Tyre-road Contact Forces?

- F_z
- F_x / F_y
- $F_x = F_z \cos(\alpha_t) \cos(\gamma) \lambda$
- $F_y = F_z \sin(\alpha_t) \cos(\gamma) \lambda$
- α_t γ λ

2.2.1

- $\lambda = \frac{v - \omega r \cos(\alpha_t)}{\max\{v, \omega r \cos(\alpha_t)\}}$
- $\alpha_t \approx 0$ $v \geq \omega r$ $\lambda = \frac{v - \omega r}{v}$
- $\lambda = 0$
- $\lambda = 1$ ABS

2.2.2

- F_z
- $\mu_x = F_x / F_z$
- $\mu_y = F_y / F_z$
- $F_x = F_z \mu_x(\alpha_t, \gamma, \lambda)$
- $F_y = F_z \mu_y(\alpha_t, \gamma, \lambda)$
- F_x, F_y F_z

2.2.1 Pacejka Magic Formula?

- **Pacejka Magic Formula** F_z α_t γ F_x, F_y
- $F_x = D_x \sin\{C_x \arctan[B_x \kappa - E_x(\cdot)]\}$
- κ slip D_x, C_x, B_x, E_x
- α_t
- **Pacejka**

2.2.1 Burckhardt

- Burckhardt $\mu(\lambda; \vartheta_r) = \vartheta_{r1} \text{bigl}(1 - e^{-\lambda \vartheta_{r2}}\bigr) - \lambda \vartheta_{r3}$
- $\vartheta_r = [\vartheta_{r1}, \vartheta_{r2}, \vartheta_{r3}]$
- $\mu_{\text{peak}} \approx 1.2 \mu(\lambda)$
 - o $\mu(\lambda)$ λ_{peak}
 - o $\lambda = 0$ $\lambda = 1$

“ $\mu(\lambda) = c \sin(b \arctan(a\lambda))$
 Burckhardt/ Pacejka Simulink Plant

2.3 Single-corner Model??????

- $J \dot{\omega} = -T_b - r F_x$
- $m \dot{v} = F_x$
- $F_x = F_z \mu(\lambda)$ $\lambda = (v - \omega r)/v$
- QuarterCar Plant $-T_b$ $+T_{\text{drive}}$

2.5.1 ????????????

- $v \dot{\lambda} = \lambda \dot{\omega} - \omega$ $\dot{\lambda} = -\frac{1-\lambda}{\omega} \dot{\omega} - 1$ $\Psi(\lambda) \approx r F_z \mu(\lambda)$
- T_b $\Psi(\lambda)$ λ_1 $\mu(\lambda)$ λ_2 $T_b > \max_{\lambda} \Psi(\lambda)$ $\lambda \rightarrow 1$

“ μ
 ABS/TC λ

2.5.1 ??????????????

- $\frac{\partial \mu}{\partial \lambda}(\lambda, v, T_b)$
 - $\Delta T_b = T_b - \bar{T}_b$
 - $\Delta \lambda = \lambda - \bar{\lambda}$
- Taylor
 - $\mu(\lambda) \approx \mu(\bar{\lambda}) + \mu_1(\bar{\lambda}) \Delta \lambda$
 - $\mu_1(\bar{\lambda}) = \frac{\partial \mu}{\partial \lambda} \Big|_{\bar{\lambda}}$
- $\Delta T_b \rightarrow \Delta \lambda$

$$G_\lambda(s) = \frac{\Delta \lambda(s)}{\Delta T_b(s)} = \frac{r}{Jv}, \frac{1}{s + a(\bar{\lambda})}$$
 - $a(\bar{\lambda})$ $\mu(\bar{\lambda})$, $\mu_1(\bar{\lambda})$, m , J , r , v
 - linearisation μ
- ω $\eta = -\dot{v}/g$ SISO

 \dots

“ \dots PI/PID \dots PI lambda-loop \dots ”

2.4 / 2.5.2 Double-corner Model????? + ??????

- λ_f, λ_r F_{zf}, F_{zr}
- 2x2 MIMO**

$$\begin{bmatrix} \Delta \lambda_f & \Delta \lambda_r \end{bmatrix} = \begin{bmatrix} G_{ff}(s) & G_{fr}(s) \\ G_{rf}(s) & G_{rr}(s) \end{bmatrix} \begin{bmatrix} \Delta T_{bf} \\ \Delta T_{br} \end{bmatrix}$$
- G_{ff}, G_{rr} single-corner
 - G_{fr}, G_{rf}
 - SISO ABS/TC

“ \dots FSAE \dots ABS \dots MIMO \dots slip \dots relative slip \dots robust \dots ”

TC T_{drive} $\min() / \text{saturator}$ PI λ
 ABS

3.6 ??????????

- Single-corner + EMB
 - open-loop vs slip control
 - K_p, K_i λ settling time
 - Burckhardt μ
- - $\lambda(t)$ $v(t)$ $T_b(t)$
 - K_p/K_i

“ FSAE TC simulation K_p/K_i μ
 $\lambda(t)$ $a_x(t)$ $\text{wheel torque}(t)$
 STM32

3.7 ?? / ??????Activation & Deactivation?

- ABS/TC
 - - $> 10 \text{ km/h}$
 - ABS TC
 -
 - - $< \text{ km/h}$
 - λ η
- traction mode

3.8 ?? Double-corner ????????

- Ch2 double-corner / slip control
- - slip controller full
 - MIMO
 - **relative slip** $\lambda_r - \lambda_f$ robust
 - +

