„Vehicle Dynamics Modelling and Simulation”

ROZDZIAŁ 7

Budowa opony

1 – bieżnik, powierzchnia toczna

2 – osnowa

3 – opasanie

4 – drutówka (bead ring)

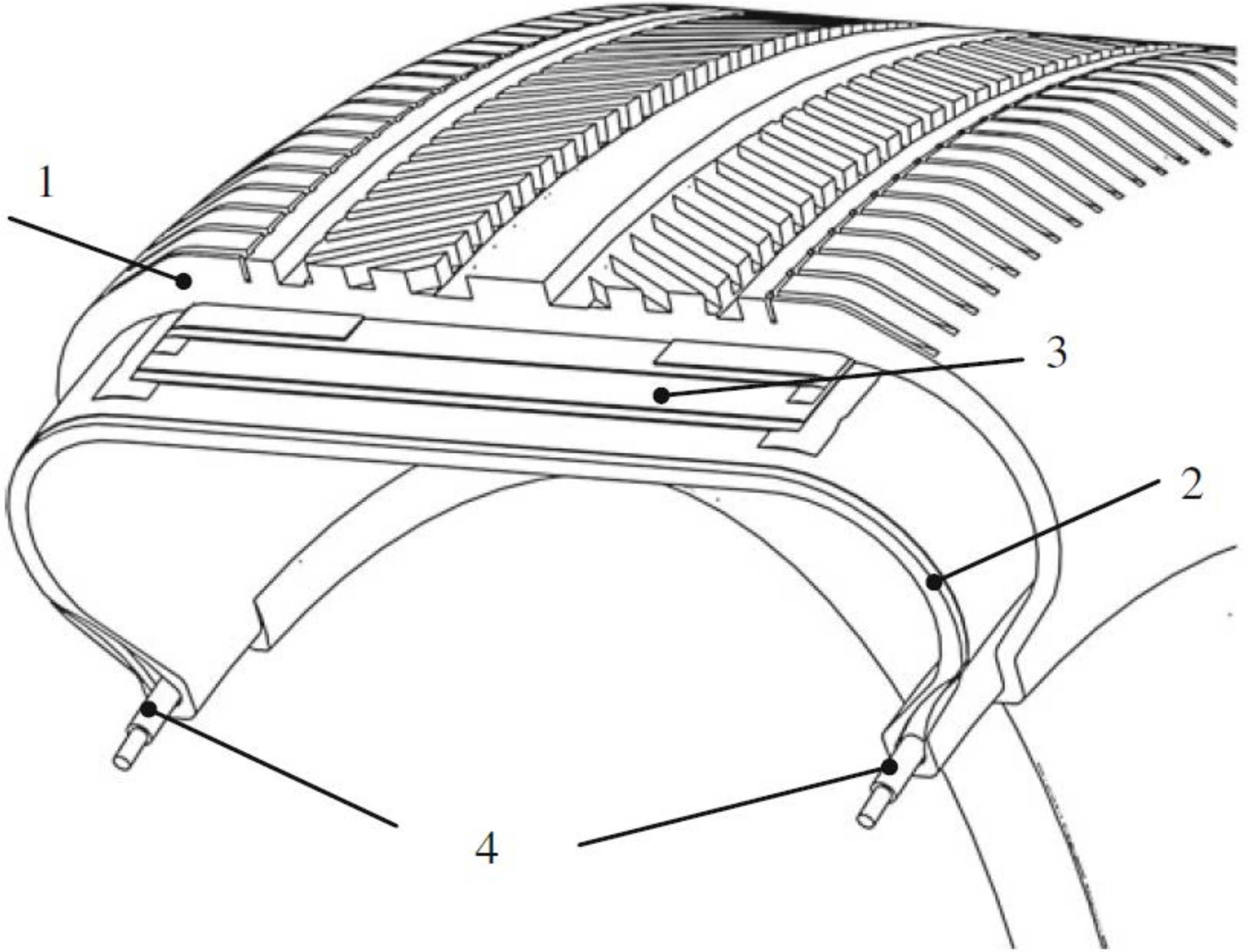


Fig. 7.1 Basic construction of a radial tire

Rozkład sił

Fig. 7.2 Contact forces between road surface and tire

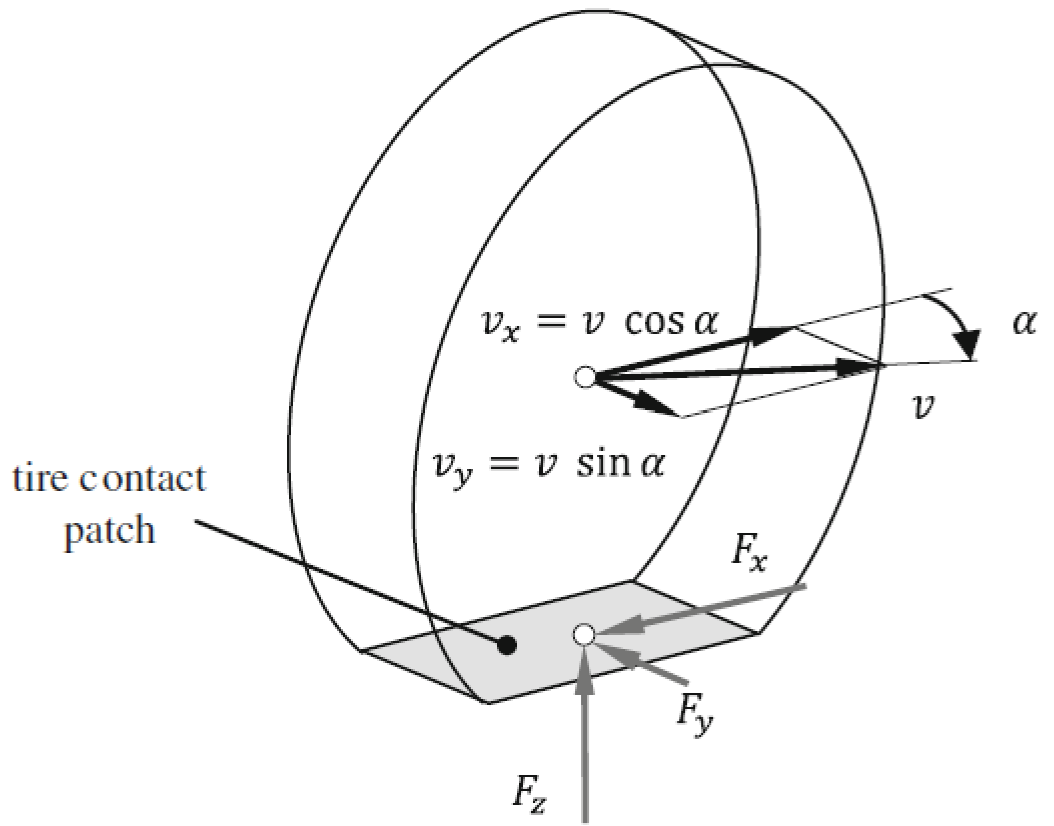


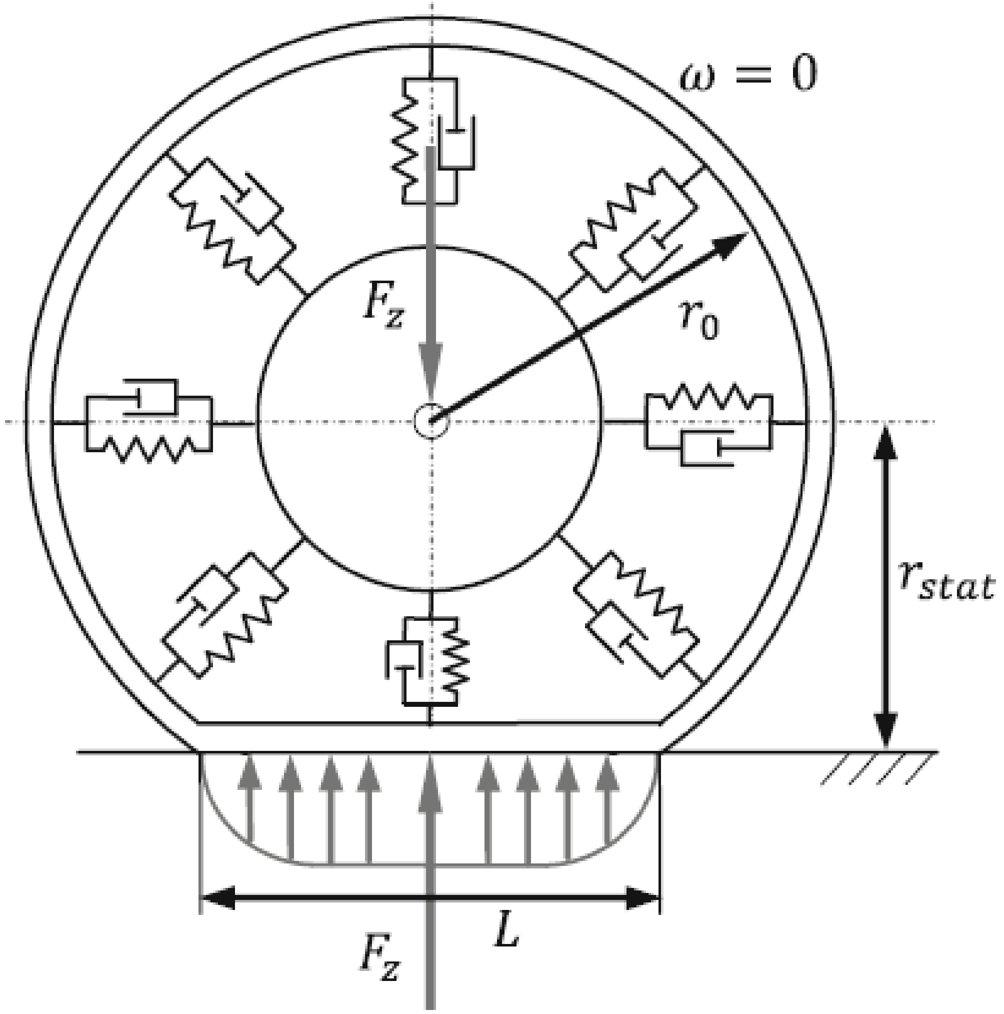
Table 7.1 Components of the contact forces at the tires

Direction	Force description	Symbol
Longitudinal, circumferential	Longitudinal force, circumferential force	F_x
Transversal, lateral	Transversal force, side force, lateral force	F_y
Vertical	Vertical force, upward force, tire contact force	F_z

Ugięcie statyczne

$$\Delta r = r_0 - r_{stat}$$

$$L \approx 2\sqrt{2} r_0 \Delta r$$

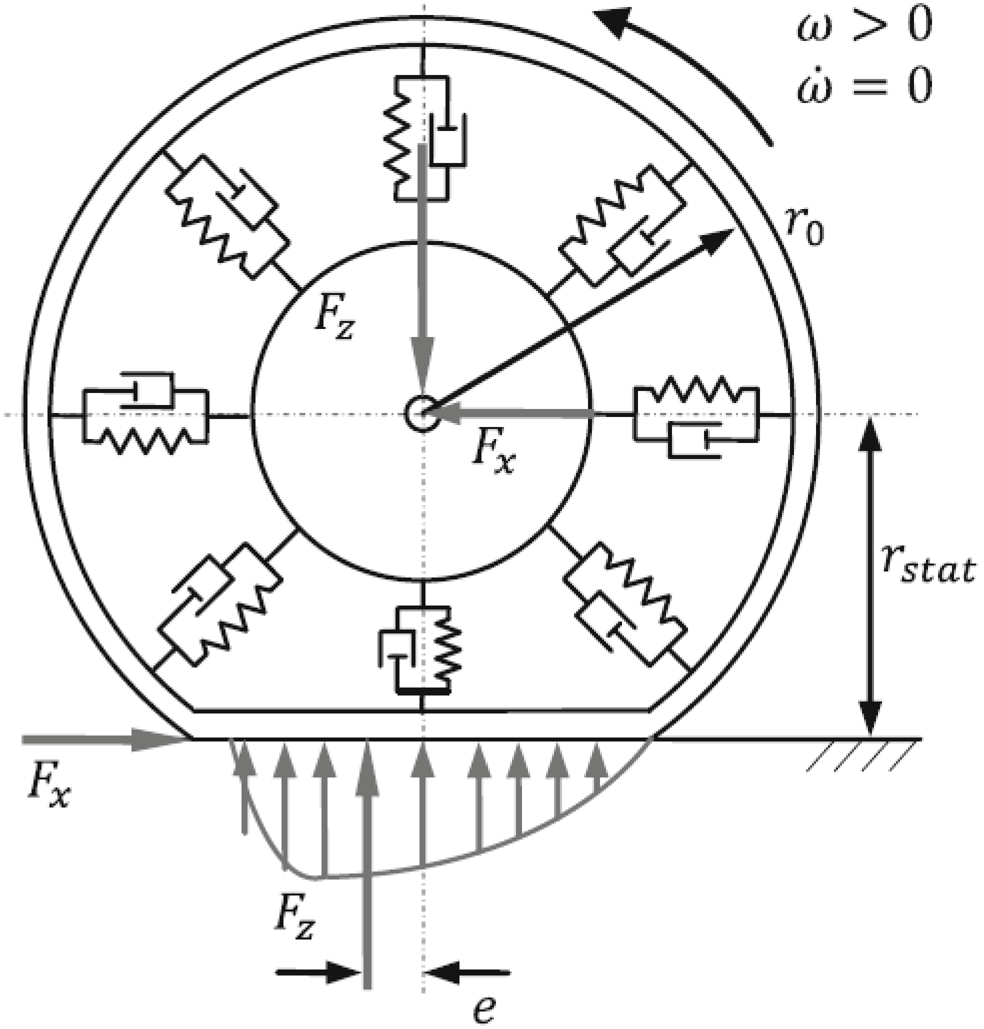


Opór toczenia

$$F_x r_{stat} - F_z e = 0$$

$$F_R = F_x = \frac{e}{r_{stat}} F_z.$$

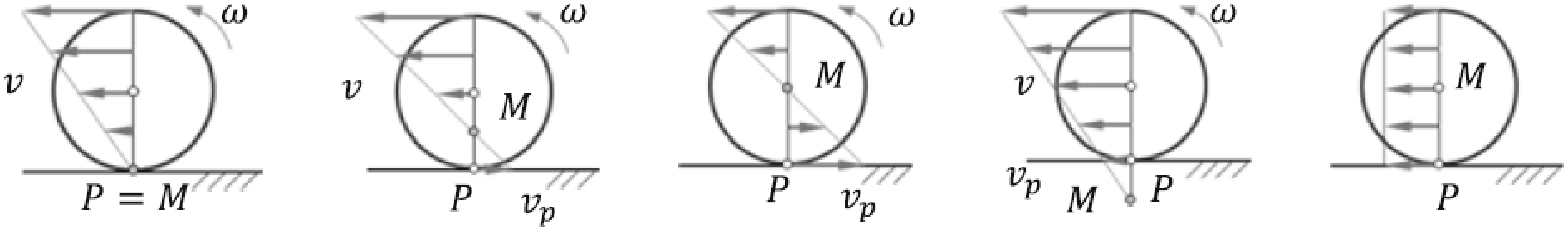
$$\mu = \frac{F_x}{F_z}.$$



Poślizg wzdłużny

Table 7.2 Rigid body slip

$v = \omega r$	$v < \omega r$		$v > \omega r$	
Rolling wheel	Driven wheel	Spinning wheel	Braked wheel	Blocked wheel



Rolling wheel	Driven wheel	Spinning wheel	Braked wheel	Blocked wheel
No slip	Drive slip		Brake slip	
$s_A = 0$ $s_B = 0$	$s_A = \dfrac{v_P}{\omega r} = \dfrac{\omega r - v}{\omega r}$	$s_A = 1$	$s_B = \dfrac{v_P}{v} = \dfrac{v - \omega r}{v}$	$s_B = 1$

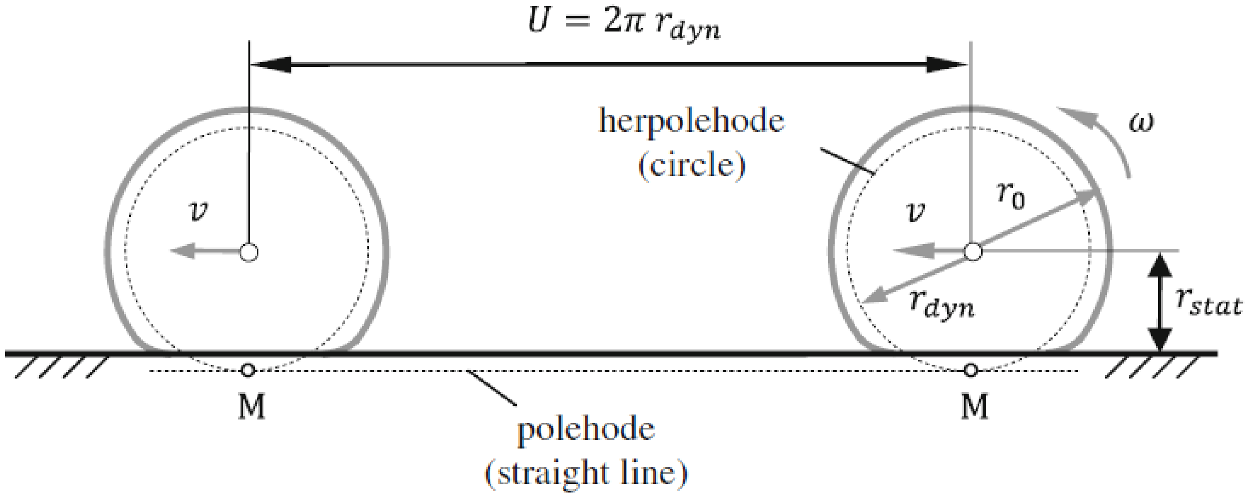
Obwód toczenia i promień dynamiczny

$$r_{dyn} = \frac{U}{2\pi}$$

$$U = r_{dyn}\alpha = r_0 \sin\alpha \to r_{dyn} = r_0 \frac{\sin\alpha}{\alpha} \approx r_0(1 - \frac{\alpha^2}{6}).$$

$$r_{stat} = r_0 \cos\alpha \approx r_0\left(1 - \frac{\alpha^2}{2}\right) \to \frac{\alpha^2}{2} \approx (1 - \frac{r_{stat}}{r_0})$$

$$r_{dyn} \approx r_0\left(1 - \frac{\alpha^2}{6}\right) \approx r_0\left(1 - \frac{1}{3} + \frac{r_{stat}}{3r_0}\right) = \frac{2}{3}r_0 + \frac{1}{3}r_{stat}$$



$$s_A = \frac{\omega r_{dyn} - v}{\omega r_{dyn}}$$

$$s_B = \frac{v - \omega r_{dyn}}{v}$$

Prędkość poślizgu

$$v_P = v - \omega r_{dyn}.$$

- Slip-less motion: $v = \omega r_{dyn} \rightarrow v_P = 0$
- Driven wheel $v < \omega r_{dyn} \rightarrow v_P < 0$
- Braked wheel: $v > \omega r_{dyn} \rightarrow v_P > 0$

Odkształcenie

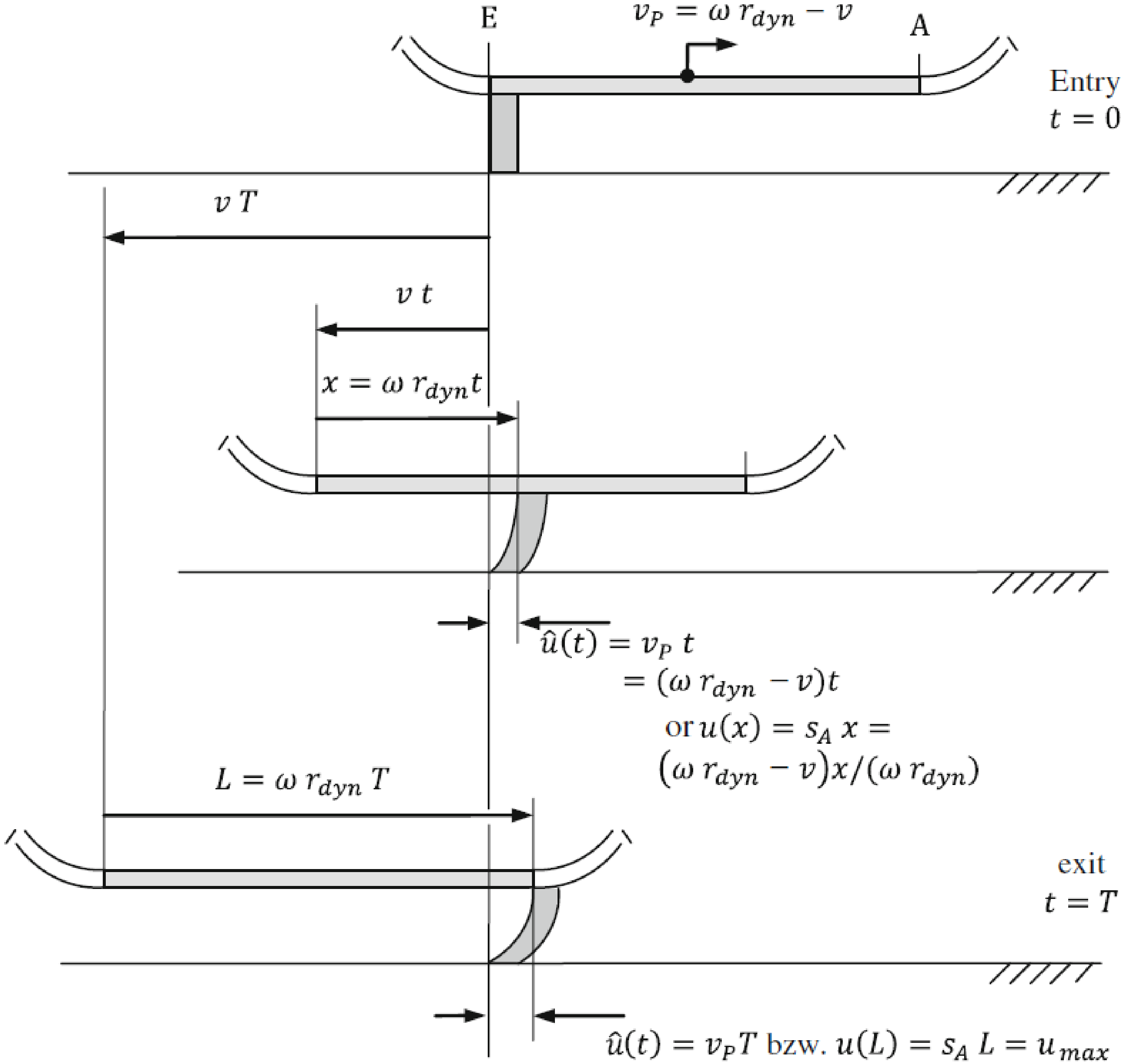
$$x = \omega r_{dyn} t$$

$$\hat{u}(t) = v_P t = (\omega r_{dyn} - v)t$$

$$u(x) = (\omega r_{dyn} - v)\frac{x}{\omega r_{dyn}} = s_A x$$

$$T = \frac{L}{\omega r_{dyn}}$$

$$u_{max} = u(L) = s_A L$$



Naprężenia styczne

$$\tau_x(x) = ku(x)$$

- Profil
- Moduł sprężystości
- Wysokość bieżnika

$$F_x = \int_A \tau_x(x)\, dA = \int_0^L \tau_x(x) b\, dx = \frac{1}{2} k b L^2 s_A$$

Adhezja

Siła pionowa

$$F_Z = \int_A p_Z(x)\, dA = \int_0^L p_Z(x) b\, dx$$

Warunek dla naprężeń stycznych

$$\tau_x(x) \leq \tau_{xH}(x) \quad \text{with} \quad \tau_{xH}(x) = \mu_H\, p_Z(x)$$

Naprężenia podczas poślizgu

$$\tau_{xG}(x) = \mu_G\, p_Z(x)$$

Tarcie opony o asfalt

$$\mu_G < \mu_H \rightarrow \tau_{xG}(x) < \tau_{xH}(x) = \mu_H\, p_Z(x)$$

Krzywa siły poślizgu

Siła obwodowa i sztywność

$$F_x = c_s s$$

$$c_s = \frac{1}{2} k b L^2$$

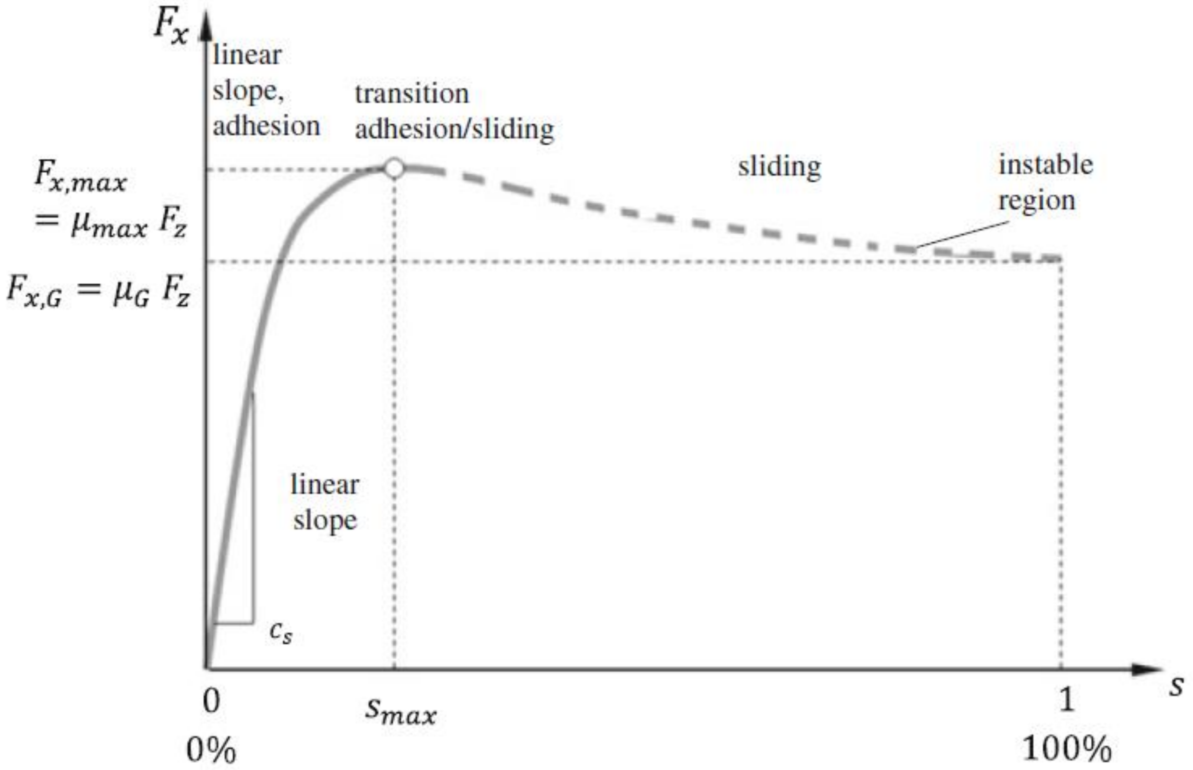
Współczynnik przyczepności max

$$\mu_{max} = \frac{F_{x,max}}{F_Z}$$

$$\mu_{max} < \mu_H$$

Współczynnik tarcia ślizgowego

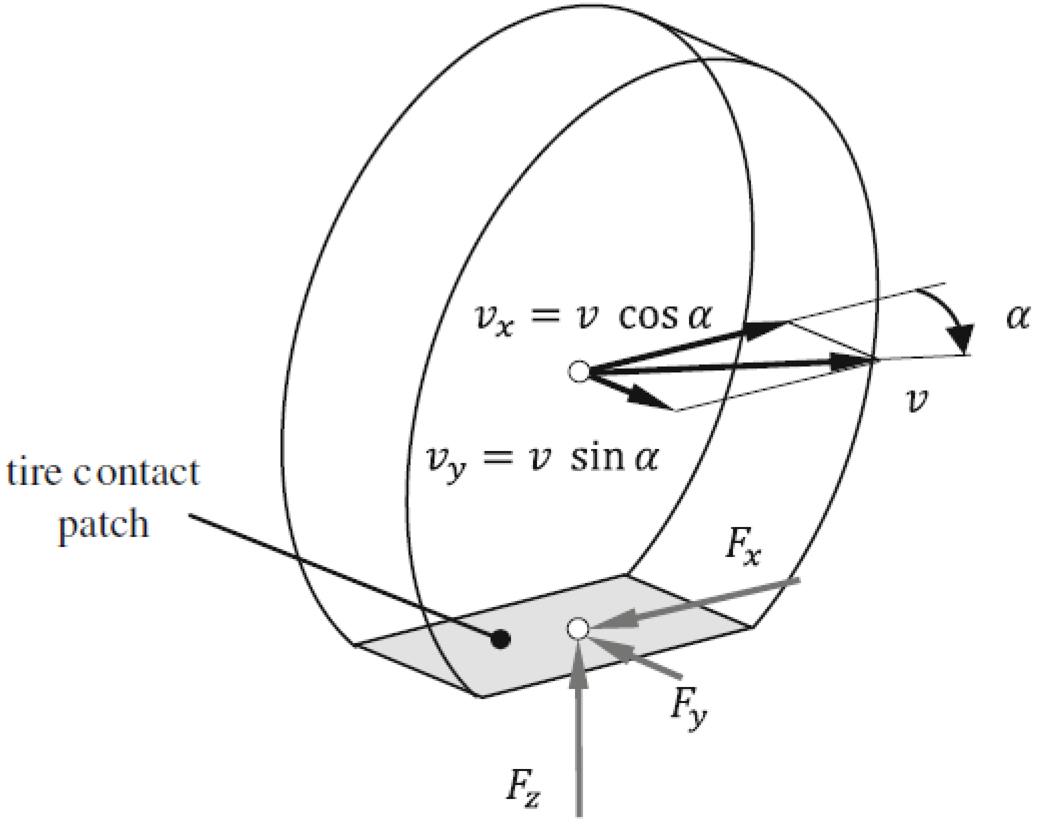
$$\mu_G = \frac{F_{x,G}}{F_Z}.$$



Kąt poślizgu, siła boczna

$$\tan\alpha = \frac{v_y}{v_x} \qquad \sin\alpha = \frac{v_y}{v}$$

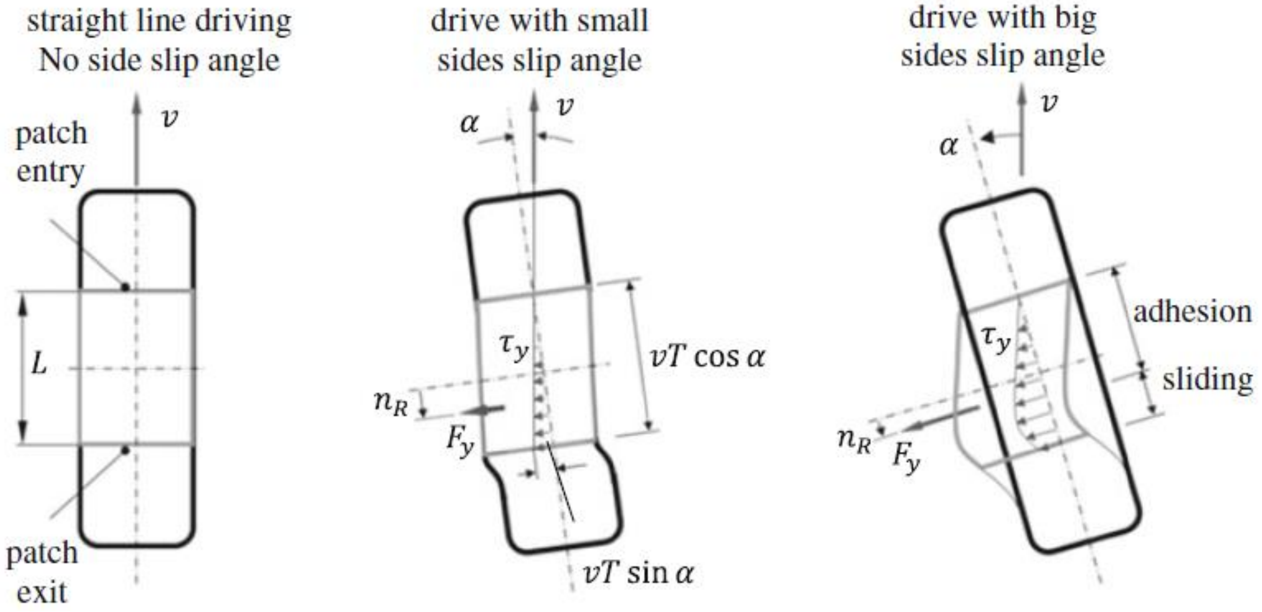
$$F_y = c_\alpha \sin\alpha \cos\alpha$$



Moment obrotowy

$$M_z = n_R F_y$$

$$n_R \approx \frac{1}{6} L$$

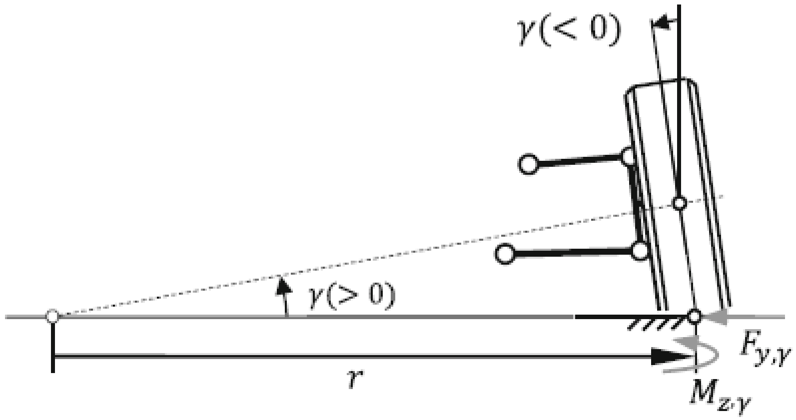


Wpływ kąta pochylenia koła

Dla kąta pochylenia koła <5st

$$F_{y,\gamma} = -c_\gamma \gamma$$

$$M_{z,\gamma} = -c_{M,\gamma} \gamma$$



Superpozycja

$$\sqrt{F_x^2 + F_y^2} \leq \mu_{max} F_z$$