Nomenclature

a1, a2, a3	Distances for six-mass approximation
a, b	Distance from CM to front and rear axles, respectively
$\mathbf{a_{11} \ldots a_{22}}$	Elements of a matrix (generic)
$\mathbf{\{a_I\}_1}$	Unit vector at marker I resolved parallel to frame 1 (GRF)
$\mathbf{\{a_J\}_1}$	Unit vector at marker J resolved parallel to frame 1 (GRF)
$\mathbf{a_x}$	Longitudinal acceleration (Wenzel model)
$\mathbf{a_y}$	Lateral acceleration (Wenzel model)
b	Longitudinal distance of body mass centre from front axle
c	Damping coefficient
c	Longitudinal distance of body mass centre from rear axle
c	Specific heat capacity of brake rotor
d	Wire diameter
$\left(\frac{\mathbf{dB}}{\mathbf{dFz}}\right)$	Variation in scaling factor with load (Harty Model)
$\mathbf{\{d_{IJ}\}_1}$	Position vector of marker I relative to J resolved parallel to frame 1 (GRF)
$\mathbf{e_1}$	Path error
f	Natural frequency (Hz)
g	Gravitational acceleration
h	Brake rotor convection coefficient
h	Height of body mass centre above roll axis
i	Square root of −1
k	Path curvature
k	Radius of gyration
k	Stiffness
k	Spring constant in hysteretic model
k	Tyre spring constant
$\mathbf{k_1, k_2}$	Front and rear ride rates, respectively
$\mathbf{k_s}$	Spring stiffness
$\mathbf{k_w}$	Stiffness of equivalent spring at the wheel centre
l	Length of pendulum
m	Mass of a body
$\mathbf{m\{g\}_1}$	Weight force vector for a part resolved parallel to frame 1 (GRF)
$\mathbf{m_t}$	Mass of tyre
n	Number of active coils
n	Number of friction surfaces (pads)
p	Brake pressure
$\mathbf{q_j}$	Set of part generalised coordinates
r	Yaw rate
$\mathbf{r_1, r_2, r_3}$	Coupler constraint rotations
$\mathbf{\{r_I\}_1}$	Position vector of marker I relative to frame i resolved parallel to frame 1 (GRF)
$\mathbf{\{r_J\}_1}$	Position vector of marker J relative to frame j resolved parallel to frame 1 (GRF)

$\mathbf{r_u}$	Unladen radius
$\mathbf{r_l}$	Laden radius
$\mathbf{r_w}$	Wheel radius
$\mathbf{s_1, s_2, s_3}$	Coupler constraint scale factors
$\mathbf{t_f}$	Front track
$\mathbf{t_r}$	Rear track
$\mathbf{v_{cog}}$	Centre of gravity (Wenzel model)
$\mathbf{v_x}$	Longitudinal velocity (Wenzel model)
$\mathbf{v_y}$	Lateral velocity (Wenzel model)
$\mathbf{x}$	Generic variable for describing tanh function
$\mathbf{x_i, y_i, z_i}$	Coordinates of each of the six masses in the six-mass approximation
$\mathbf{x_i, y_i, z_i}$	Components of the ith eigenvector
$\mathbf{x(t)}$	Function of time (generic)
$\mathbf{x_{CM}, y_{CM}, z_{CM}}$	Coordinates of body centre of mass
$\mathbf{\{x_I\}_1}$	Unit vector along x-axis of marker I resolved parallel to frame 1 (GRF)
$\mathbf{\{y_I\}_1}$	Unit vector along y-axis of marker I resolved parallel to frame 1 (GRF)
$\mathbf{\{x_J\}_1}$	Unit vector along x-axis of marker J resolved parallel to frame 1 (GRF)
$\mathbf{\{y_J\}_1}$	Unit vector along y-axis of marker J resolved parallel to frame 1 (GRF)
$\mathbf{y_s}$	Asymptotic value at large slip (Magic Formula)
$\mathbf{z}$	Auxiliary state variable
$\mathbf{z}$	Heave displacement variable
$\mathbf{\{z_I\}_1}$	Unit vector along z-axis of marker I resolved parallel to frame 1 (GRF)
$\mathbf{\{z_J\}_1}$	Unit vector along z-axis of marker J resolved parallel to frame 1 (GRF)
$\mathbf{A}$	Area
$\mathbf{A}$	Linear acceleration
$\mathbf{A, B, C}$	Intermediate terms in a cubic equation
$\mathbf{A}$	Scaling for solution form of a differential equation (generic)
$\mathbf{A}$	Step height
$\mathbf{A_c}$	Convective area of brake disc
$\mathbf{[A_{1n}]}$	Euler matrix for part n
$\mathbf{\{A_n\}_1}$	Acceleration vector for part n resolved parallel to frame 1 (GRF)
$\mathbf{A^p}$	Centripetal acceleration
$\mathbf{\{A^p{}_{PQ}\}_1}$	Centripetal acceleration vector P relative to Q referred to frame 1 (GRF)
$\mathbf{\{A^t{}_{PQ}\}_1}$	Transverse acceleration vector P relative to Q referred to frame 1 (GRF)
$\mathbf{\{A^c{}_{PQ}\}_1}$	Coriolis acceleration vector P relative to Q referred to frame 1 (GRF)
$\mathbf{\{A^s{}_{PQ}\}_1}$	Sliding acceleration vector P relative to Q referred to frame 1 (GRF)
$\mathbf{A_{vehicle}}$	Acceleration of vehicle

$\mathbf{A_X}$	Longitudinal curvature factor
$\mathbf{A_y}$	Lateral acceleration
AyG	Lateral acceleration gain
B	Load scaling factor (Harty Model)
B	Stiffness factor (Magic Formula)
[B]	Transformation matrix from frame O_e to O_n
BKid	Bottom kingpin marker
BM	Bump movement
$\mathbf{B_T}$	Brake torque
C	Shape factor (Magic Formula)
[C]	Compliance matrix
$\mathbf{C_{D0}}$	Drag coefficient at zero aerodynamic yaw angle
$\mathbf{C_{D\beta}}$	Drag coefficient sensitivity to aerodynamic yaw angle
$\mathbf{C_F}$	Front axle cornering stiffness
$\mathbf{C_\gamma}$	Camber coefficient
$\mathbf{C_{L0}}$	Coefficient of lift at zero angle of attack
$\mathbf{C_{L\alpha}}$	Variation in coefficient of lift with angle of attack
$\mathbf{C_{MX}}$	Overturning moment coefficient
$\mathbf{C_r}$	Rolling resistance moment coefficient
$\mathbf{C_R}$	Rear axle cornering stiffness
$\mathbf{C_S}$	Tyre longitudinal stiffness
$\mathbf{C_p}$	Process capability
CP	Centre of pressure
$\mathbf{C_\alpha}$	Tyre lateral stiffness due to slip angle
$\mathbf{C_{\alpha f}}$	Front tyre lateral stiffness due to slip angle
$\mathbf{C_{\alpha r}}$	Rear tyre lateral stiffness due to slip angle
$\mathbf{C_\gamma}$	Tyre lateral stiffness due to camber angle
D	Clipped camber scale constant
D	Mean coil diameter
D	Peak value (Magic Formula)
DZ	Displacement variable (generic)
DM(I,J)	Magnitude of displacement of I marker relative to J marker
DX(I,J)	Displacement in X-direction of I marker relative to J marker parallel to GRF
DY(I,J)	Displacement in Y-direction of I marker relative to J marker parallel to GRF
DZ(I,J)	Displacement in Z-direction of I marker relative to J marker parallel to GRF
E	Camber clip curvature constant
E	Young's modulus of elasticity
E	Curvature factor (Magic Formula)
F	Aerodynamics force
F	Applied force
F	Force generated by hysteretic model
F	Spring force
Fhyst	Amplitude of hysteretic force
Fhyst	Final outcome from sequence of hysteretic calculations
$\mathbf{\{F_{nA}\}_1}$	Applied force vector on part n resolved parallel to frame 1 (GRF)

$\{F_{nC}\}_1$	Constraint force vector on part n resolved parallel to frame 1 (GRF)
F_{FRC}	Lateral force reacted by front roll centre
F_{RRC}	Lateral force reacted by rear roll centre
F_x	Frictional force
F_x	Longitudinal tractive or braking tyre force
Fx_1	Friction moderated longitudinal load in moderate slip
Fx_2	Friction moderated longitudinal load in deep slip
F_y	Lateral tyre force
F_{Y1}	Friction moderated lateral load at moderate slip angles
F_{Y2}	Friction moderated lateral load at deep slip angles
F'_y	Lagged (relaxed) side force
$F_{y\alpha}$	Lateral load due to slip angle
$F_{y\alpha'}$	Friction moderated side force due to slip angle
$F_{y\gamma}$	Lateral load due to camber/inclination angle
$F_{y\gamma'}$	Friction moderated side force due to camber/inclination angle
$\frac{\widehat{Fy}}{\mu Fz}$	Lateral capacity fraction
F_z	Normal force
F_z	Vertical tyre force
F_z	Time varying tyre load
F_{z0}	Static corner load
F_{zc}	Vertical tyre force due to damping
F_{zk}	Vertical tyre force due to stiffness
$\{F_A\}_1$ $\{F_B\}_1\ldots$	Applied force vectors at points A, B,… resolved parallel to frame 1 (GRF)
$[F_E]$	Elastic compliance matrix (concept suspension)
F_D	Drag force
FG	Fixed ground marker
G	Shear modulus
GC	Gravitational constant
GO	Ground level offset
GRF	Ground reference frame
$\{H\}_1$	Angular momentum vector for a body
$H(\omega)$	Transfer function
HTC	Half track change
I	Mass moment of inertia
I	Second moment of area
I_2	Pitch inertia of vehicle
I_1, I_2, I_3	Principal mass moments of inertia of a body
I_{wheel}	Mass moment of inertia of road wheel in the rolling direction
$I_{xx}, I_{yy}, I_{zz}, I_{xy}, I_{yz}, I_{xz}$	Components of inertia tensor
ICY	Y-coordinate of instant centre
ICZ	Z-coordinate of instant centre
$[I_n]$	Inertia tensor for a part
J	Polar second moment of area
Jz	Vehicle body yaw inertia (Wenzel model)
K	Drive torque controller constant
K	Spring stiffness

$\mathbf{K}$	Stability factor
$\mathbf{K}$	Understeer gradient
$\mathbf{K_z}$	Tyre radial stiffness
$\mathbf{K_T}$	Torsional stiffness
$\mathbf{K_{Ts}}$	Roll stiffness due to springs
$\mathbf{K_{Tr}}$	Roll stiffness due to anti-roll bar
$\mathbf{L}$	Contact patch length
$\mathbf{L}$	Length
$\mathbf{L}$	Wheelbase
$\mathbf{\{L\}_1}$	Linear momentum vector for a particle or body
$\mathbf{L_{PFZ2}}$	Pneumatic lead scaling factor with load squared
$\mathbf{L_{PFZ}}$	Pneumatic lead scaling factor with load
$\mathbf{L_{PC}}$	Pneumatic lead at reference load
LPRF	Local part reference frame
$\mathbf{L_R}$	Tyre relaxation length
$\mathbf{M_{FRC}}$	Moment reacted by front roll centre
$\mathbf{\{M_{nA}\}_e}$	Applied moment vector on part n resolved parallel to frame e
$\mathbf{\{M_{nC}\}_e}$	Constraint moment vector on part n resolved parallel to frame e
$\mathbf{M_s}$	Equivalent roll moment due to springs
$\mathbf{M_x}$	Tyre overturning moment
$\mathbf{M_{X\gamma\kappa}}$	Overturning moment due to longitudinal forces
$\mathbf{M_y}$	Moment about y-axis
$\mathbf{M_y}$	Tyre rolling resistance moment
$\mathbf{M_z}$	Tyre self aligning moment
$\mathbf{M_{z\alpha}}$	Friction moderated side force due to slip angle
$\mathbf{M_{z\gamma}}$	Friction moderated side force due to camber/inclination angle
$\mathbf{M_{Z\gamma\kappa}}$	Aligning moment due to longitudinal forces
MRF	Marker reference frame
$\mathbf{M_{RRC}}$	Moment reacted by rear roll centre
$\mathbf{N_r}$	Vehicle yaw moment with respect to yaw rate
$\mathbf{[N_t]}$	Norsieck vector
$\mathbf{N_{vy}}$	Vehicle yaw moment with respect to lateral velocity
$\mathbf{O_1}$	Frame 1 (GRF)
$\mathbf{O_e}$	Euler axis frame
$\mathbf{O_i}$	Reference frame for part i
$\mathbf{O_j}$	Reference frame for part j
$\mathbf{O_n}$	Frame for part n
$\mathbf{O_P}$	Lateral offset of contact patch
$\mathbf{P_0}$	Initial tyre pressure at zero load
$\overline{P}$	Average footprint pressure
$\mathbf{\{P_{nr}\}_1}$	Rotational momenta vector for part n resolved parallel to frame 1 (GRF)
$\mathbf{\{P_{nt}\}_1}$	Translational momenta vector for part n resolved parallel to frame 1 (GRF)
Pt	Constant power acceleration
$\mathbf{P_{\Delta z}}$	Change in nominal pressure
$\mathbf{P_{\Delta z}}$	Pressure due to tyre vertical deflection
QG	Position vector of a marker relative to the GRF

QP	Position vector of a marker relative to the LPRF
R	Radius (generic)
R	Radius of turn
R	Fraction of roll moment distributed between front and rear axles
$\mathbf{R_1}$	Unloaded tyre radius
$\mathbf{R_2}$	Tyre carcass radius
$\mathbf{R_d}$	Radius to centre of brake pad
$\mathbf{R_e}$	Effective rolling radius
$\{\mathbf{R_i}\}_1$	Position vector of frame i on part i resolved parallel to frame 1 (GRF)
$\{\mathbf{R_j}\}_1$	Position vector of frame j on part j resolved parallel to frame 1 (GRF)
$\mathbf{R_l}$	Loaded tyre radius
$\{\mathbf{R_n}\}_1$	Position vector for part n resolved parallel to frame 1 (GRF)
$\{\mathbf{R_p}\}_1$	Position vector of tyre contact point P relative to frame 1, referenced to frame 1
$\mathbf{R_u}$	Unloaded tyre radius
$\{\mathbf{R_w}\}_1$	Position vector of wheel centre relative to frame 1, referenced to frame 1
$\{\mathbf{R_{AG}}\}_n$	Position vector of point A relative to mass centre G resolved parallel to frame n
$\{\mathbf{R_{BG}}\}_n$	Position vector of point B relative to mass centre G resolved parallel to frame n
$\mathbf{RC_{front}}$	Front roll centre
$\mathbf{RC_{rear}}$	Rear roll centre
RCY	Y-coordinate of roll centre
RCZ	Z-coordinate of roll centre
$\mathbf{R_Z}$	Reference load (Harty Model)
S	Distance travelled
SA	Spindle axis reference point
$\mathbf{S_{CX}}$	Critical slip ratio
$\mathbf{S_e}$	Error variation
Sh	Horizontal shift (Magic Formula)
Sv	Vertical shift (Magic Formula)
$\mathbf{S_L}$	Longitudinal slip ratio
$\mathbf{S_L}^*$	Critical value of longitudinal slip
SN	Signal-to-noise ratio
$\mathbf{S_T}$	Total variation
$\mathbf{S}_\alpha$	Lateral slip ratio
$\mathbf{S}_{\mathbf{L}\alpha}$	Comprehensive slip ratio
$\mathbf{S}_\alpha^*$	Critical slip angle
$\mathbf{S}_\kappa$	Variation due to linear effect
T	Camber clipping threshold fraction
T	Kinetic energy for a part
T	Temperature
T	Torque
$\mathbf{T_B}$	Brake torque
$\mathbf{T_{env}}$	Environmental temperature

$\mathbf{T_{PFZ2}}$	Pneumatic trail scaling factor with load squared
$\mathbf{T_{PFZ}}$	Pneumatic trail scaling factor with load
$\mathbf{T_{PC}}$	Pneumatic trail scaling constant
$\mathbf{T_S}$	Spin up torque
$\mathbf{T_0}$	Initial brake rotor temperature
$\{\mathbf{T_A}\}_1$ $\{\mathbf{T_B}\}_1\ldots$	Applied torque vectors at points A, B,… resolved parallel to frame 1 (GRF)
TK	Top kingpin marker
TR	Suspension trail
$\{\mathbf{U_r}\}$	Unit vector normal to road surface at tyre contact point
$\{\mathbf{U_s}\}$	Unit vector acting along spin axis of tyre
UCF	Units consistency factor
US	Understeer
V	Forward velocity
$\mathbf{V_0}$	Initial tyre volume at zero load
$\mathbf{V_a}$	Actual forward velocity
$\mathbf{V_e}$	Error variance
$\mathbf{V_g}$	Ground plane velocity
$\mathbf{V_{lowlimit}}$	Limiting velocity
$\{\mathbf{V_n}\}_1$	Velocity vector for part n resolved parallel to frame 1 (GRF)
$\{\mathbf{V_p}\}_1$	Velocity vector of tyre contact point P referenced to frame 1
$\mathbf{V_s}$	Desired simulation velocity
$\mathbf{V_x}$	Sliding velocity
$\mathbf{V_{xc}}$	Longitudinal slip velocity of tyre contact point
Vy	Lateral slip velocity of tyre contact point
Vz	Vertical velocity of tyre contact point
Vref	Reference velocity in hysteretic model
VR(I,J)	Radial line of sight velocity of I marker relative to J marker
VZ	Velocity variable (generic)
$\mathbf{V_{\Delta z}}$	Reduced tyre cavity volume
W	Tyre width
WB	Wheelbase marker
WC	Wheel centre marker
WF	Wheel front marker
WR	Wheel recession
XP	Position vector of a point in a marker xz-plane
$\{\mathbf{X_{sae}}\}_1$	Unit vector acting at tyre contact point in X_{sae} direction referenced to frame 1
$\mathbf{Y_r}$	Vehicle side force with respect to yaw rate
$\mathbf{Y_{vy}}$	Vehicle side force with respect to lateral velocity
YRG	Yaw rate gain
$\{\mathbf{Y_{sae}}\}_1$	Unit vector acting at tyre contact point in Y_{sae} direction referenced to frame 1
$\{\mathbf{Z_{sae}}\}_1$	Unit vector acting at tyre contact point in Z_{sae} direction referenced to frame 1
ZP	Position vector of a point on a marker z-axis
α	Angle of attack
α	Tyre slip angle

α_{CY}	Critical slip angle (Harty Model)
$\{\alpha_n\}_1$	Angular acceleration vector for part n resolved parallel to frame 1 (GRF)
α_f	Front axle slip angle
α_r	Rear axle slip angle
β	Aerodynamic yaw angle (or body slip angle surrogate)
β	Side slip angle
$\dot{\beta}$	Rate of change of side slip angle (Beta Dot)
δ	Steer or toe angle
δ_o	Steer angle of outer wheel
δ_i	Steer angle of inner wheel
δ_{mean}	Average steer angle of inner and outer wheels
γ	Camber angle
$\{\gamma_n\}_e$	Set of Euler angles for part n
ζ	Damping ratio
κ	Longitudinal slip (Pacjeka)
κ	Sensitivity of process
θ	2nd Euler angle rotation
θ	Pendulum displacement variable
θ	Pitch displacement variable
θ_1	Orientation of the first principal axis within a plane of symmetry
λ	Eigenvalue (generic)
$\{\lambda\}_1$	Reaction force vector resolved parallel to frame 1 (GRF)
λ_d	Magnitude of reaction force for constraint d
λ_p	Magnitude of reaction force for constraint p
λ_α	Magnitude of reaction force for constraint α
μ	Friction coefficient
μ_o	Tyre to road coefficient of static friction
μ_1	Tyre to road coefficient of sliding friction
η	Signal-to-noise ratio
η	Hysteresis constant/loss factor
ρ	Density
σ	Standard deviation
σ_d	Standard deviation of attribute d
Φ	3rd Euler angle rotation
ψ	1st Euler angle rotation
ψ	Compass heading angle
$\dot{\psi}$	Yaw rate (Wenzel model)
ω	Angular frequency (rads s^{-1})
ω	Yaw rate
ω_d	Damped natural frequency
ω_d	Demanded yaw rate
ω_{err}	Yaw rate error
ω_{fns}	Front axle no-slip yaw rate
$\omega_{friction}$	Yaw rate from limiting friction
ω_{geom}	Yaw rate from geometry
ω_n	Undamped natural frequency
$\{\omega_e\}_1$	Angular velocity vector for part n resolved parallel to frame e

$\{\boldsymbol{\omega}_{\mathbf{n}}\}_{\mathbf{1}}$	Angular velocity vector for part n resolved parallel to frame 1 (GRF)
$\boldsymbol{\omega}_{\mathbf{0}}$	Angular velocity of free rolling wheel
$\boldsymbol{\omega}_{\mathbf{D}}$	Angular velocity of driven wheel
$\boldsymbol{\Delta}_{\mathbf{d}}$	Allowable range for attribute d
$\boldsymbol{\Delta}\mathbf{x}$	Change in longitudinal position of wheel (concept suspension)
$\boldsymbol{\Delta}\mathbf{y}$	Change in lateral position (half/track) of wheel (concept suspension)
$\boldsymbol{\Delta}\mathbf{z}$	Deformation of tyre
$\boldsymbol{\Delta}\mathbf{V}$	Change in tyre cavity volume
$\boldsymbol{\Delta}\varepsilon$	Change in steer angle (toe in/out) of wheel (concept suspension)
$\boldsymbol{\Delta}\boldsymbol{\gamma}$	Change in camber angle of wheel (concept suspension)
$\{\boldsymbol{\Phi}_{\mathbf{a}}\}_{\mathbf{1}}$	Vector constraint equation resolved parallel to frame 1 (GRF)
$\boldsymbol{\Phi}_{\mathbf{d}}$	Scalar constraint expression for constraint d
$\boldsymbol{\Phi}_{\mathbf{p}}$	Scalar constraint expression for constraint p
$\boldsymbol{\Phi}_{\alpha}$	Scalar constraint expression for constraint α
$\dot{\Omega}_{\mathbf{wheel}}$	Angular acceleration of road wheel