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ELECTRIC-HYDRAULIC COMPOUND CONTROL ANTI-LOCK BRAKING SYSTEM

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ABSTRACT–An anti-lock control strategy for electric-hydraulic compound braking is proposed to improve the emergency braking safety of a hub motor electric vehicle. Based on the half-vehicle braking longitudinal dynamics model, the optimal control is solved to obtain the total braking torque corresponding to each wheel. A fuzzy algorithm is used to determine the proportion coefficient of the motor based on the battery state of charge coefficient (SOC) and the motor speed constraints on the motor braking, and the total braking torque is distributed. The hydraulic and motor braking torques obtained from the allocation are input as reference values to the electric-hydraulic compound braking system, and the output braking torque is fed back into the CarSim vehicle model. The proposed electric-hydraulic compound ABS control strategy is also validated in the co-simulation of CarSim and MATLAB/Simulink on high, medium and low adhesion road surfaces.

KEY WORDS : Wheel motors, Electric-hydraulic ABS, Optimal control, Brake torque distribution, Fuzzy control

NOMENCLATURE

m	: half-vehicle mass, kg
F_{xf}	: front wheel longitudinal braking force, N
F_{xr}	: rear wheel longitudinal braking force, N
J	: wheel rotational inertia, kgm^2
ω_i	: wheel angular velocity, r/s
F_{xi}	: longitudinal wheel force, N
R	: wheel radius, m
T_{bi}	: braking moment, N·m
$\mu_{(\lambda f)}$	: front wheel road adhesion coefficient
$\mu_{(\lambda r)}$	: rear wheel road adhesion coefficient
F_{zf}	: front wheel vertical load, N
F_{zr}	: rear wheel vertical load, N
$i=f,r$	: front and rear wheels
a	: longitudinal acceleration, m/s^2
g	: gravitational acceleration, m/s^2
L_r	: distance from the centre of mass of the car to the centre line of the rear axle, m
L_f	: distance from the centre of mass of the car to the centre line of the front axle, m
L	: axle distance, m
h_g	: height of the centre of mass of the car, m
c_1, c_2, c_3	: the condition characteristic parameters related to the pavement condition
μ_p	: peak adhesion coefficient
λ_p	: slip rate corresponding to the peak adhesion coefficient
μ_s	: adhesion coefficient
ξ	: pressure regulation signal
p_m	: brake master cylinder pressure, Pa
c	: energy reservoir equivalent constant fluid pressure, Pa
c_e	: hydraulic system equivalent fluid volume
R_{e1}	: equivalent fluid resistance when increasing pressure, N
R_{e2}	: equivalent fluid resistance when increasing pressure, N
u_1, u_2	: solenoid valve control commands
k_b	: braking torque constant, N·m
τ	: hydraulic system hysteresis time, s
R_s	: stator resistance, N
Ld	: d-axis inductances, H
Lq	: q-axis inductances, H
p	: number of pole pairs of the motor
ω_s	: mechanical angular velocity of the motor, r/s
φ_f	: magnetic flux, Wb
φ_d, φ_q	: components of the magnetic flux on the d and q axes, Wb
k_t	: motor torque constant, N·m
J_e	: rotational inertia of the rotating part of the motor, kg·m
B	: damping factor

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