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Finite-time tracking control of hypersonic vehicle with input saturation

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Abstract: This paper studies the finite-time tracking control problem of hypersonic vehicle in presence of model parameter uncertainties, external disturbance and input saturation. Firstly, to cope with the unknown upper bound disturbance of the system, an adaptive fast terminal sliding mode controller is designed based on a non-homogeneous disturbance observer (NHDO) which can alleviate the chattering and make the proposed controller strongly robust. Meanwhile, a new saturation function is introduced to solve the singular problems of the controller. Secondly, to further solve the problem of input saturation, the hyperbolic tangent function and auxiliary system are introduced to design an anti-saturation fast adaptive terminal sliding mode controller which not only can satisfy the requirements of the actuator's physical limitation, but also guarantees that the sliding mode manifold is finite-time stable. Finally, Lyapunov theory is used to prove the stability of the designed controller strictly, and the numerical simulations of the longitudinal model of the hypersonic vehicle are carried out, which further confirm the robustness and effectiveness of the two designed controllers.

Keywords: Non-homogeneous disturbance observer; Hypersonic vehicle; Input saturation; Tracking control; Sliding mode control; Finite-time stable

Nomenclature

m —Mass, (kg)
S —Reference area, (m^2)
$\bar{c}$ —Mean aerodynamic chord,(m)
R_E —Earth radius, (m)
μ —Gravitational constant, (m/s^2)
h —Altitude, (m)
h_d —Reference command for altitude, (m)
C_L^{α} —First-order coefficient of α contribution to C_L
C_D —Drag coefficient
$C_D^{\alpha^i}$ — i th-order coefficient of α contribution to C_D
C_D^0 —Constant term in C_D
C_T —Thrust coefficient
β_0 and β_0' —Fuel-to-air ratio contribution to C_T^0
β_1 —Constant term in C_T^0

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