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高超声速飞行器大包线切换LPV控制方法

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Switching LPV Control Method in Wide Flight Envelope for Hypersonic Vehicles

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摘要 高超声速飞行器飞行包线和参数变化范围大,气动参数存在较强不确定性,要求控制器能够适应大的飞行包线并具有较好的鲁棒性。针对上述问题,提出一种基于间隙度量的大包线滞后切换线性变参数(LPV)控制方法。依照时变参数将设计包线划分为若干子区域,将多胞理论和间隙度量引入控制器求解,提出了基于最优间隙度量的LPV控制方法,并利用此方法独立设计各子区域的LPV控制器,以改善控制器控制性能和鲁棒性能;利用基于重叠区域的滞后切换策略实现大包线内各子区域控制器的切换,以抑制切换面附近控制器的切换抖动,并证明了切换闭环系统的稳定性;最后以某型高超声速飞行器为对象设计了大包线滞后切换LPV控制器。仿真结果表明该方法可实现控制指令的精确跟踪,提高设计包线内LPV控制器的控制性能和鲁棒性能,并能保证切换系统的稳定性。

关键词： 线性变参数控制 切换系统 高超声速飞行器 大包线 间隙度量 滞后切换

Abstract： Hypersonic vehicles traverse a broad flight envelope with a wide parameter variation range and strong parameter uncertainties. Therefore it is important to improve the controller performance and robustness in a wide envelope. A new hysteresis switching linear parameter varying (LPV) control method using polytope theory and gap-metric is presented in this paper. The design envelope is firstly divided into several sub-regions in accordance with the time-varying parameters. A new LPV control method with the optimal gap-metric is proposed, and then a family of single LPV controllers are designed independently using the new method to improve the performance and robustness, each suitable for a specific sub-region. They are switched according to the time-varying parameter trajectories using the hysteresis switching strategy based on overlap regions to avoid chattering. The stability of the closed-loop switching system is also proved. Finally, the new switching LPV design approach is applied to a hypersonic vehicle. Simulation results show that this new method can improve the performance and enhance the robustness of the LPV controllers in a wide design envelope. The performance of command tracking and the robustness of the switching LPV control system are satisfactory. The stability of the system is also guaranteed.

Keywords： linear parameter varying control switching systems hypersonic vehicle wide flight envelope gap-metric hysteresis switching

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