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基于在线滚动LS-SVR的涡轴发动机混合预测控制

王健康, 张海波, 黄向华, 段姝婧

南京航空航天大学 能源与动力学院, 江苏 南京 210016

Hybrid Predictive Control for Turbo-shaft Engine Based on Online Sliding LS-SVR

WANG Jiankang, ZHANG Haibo, HUANG Xianghua, DUAN Shujing

College of Energy and Power Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

摘要 提出了一种串级PID+非线性模型预测控制(NMPC)的混合控制方案,用于涡轴发动机控制系统中。其中:主控制回路采用串级PID控制器以消除静差保证系统稳定;带约束优化的预测控制器则用于实时燃油补偿,以增强发动机系统对直升机功率需求的快速跟随能力。该预测控制器是基于在线预测模型实现,首先在VC环境下设计在线滚动最小二乘支持向量回归机(OSLS-SVR),在线训练高精度、实时性好的内嵌式预测模型,其测试精度可达3‰;而后利用该模型与序列二次规划(SQP)算法完成滚动优化,建立预测控制器;最后,在UH-60A直升机/T700涡轴发动机综合模型仿真环境下,通过模拟直升机大幅急速升降操作,验证了该混合预测控制方案对大扰动具有较强的抑制能力及鲁棒性,从而使直升机获得更好的机动性能。

关键词： 涡轴发动机 控制系统 混合控制 预测控制 支持向量机

Abstract： A hybrid predictive control scheme for a turbo-shaft engine is proposed by combining the cascade PID control with the nonlinear model predictive control (NMPC). Through adding the predictive controller, i.e., the engine compensator, to the cascade PID controller in the main loop, the engine control system has a better control quality. The predictive controller is composed of an online predictive model and a rolling optimizer. Satisfactory model accuracy within 3‰ is achieved by online sliding least squares-support vector regression (OSLS-SVR), and the rolling optimizer is implemented using the sequential quadratic programming (SQP) algorithm. Finally, based on an integrated UH-60A helicopter/T700 turbo-shaft engine simulation platform, a large number of bob-up and bob-down flight simulation is carried out to verify the proposed control mode. The results show that the hybrid predictive control has better dynamic disturbance rejection ability and robustness, which enables the helicopter to exhibit much greater maneuverability than the conventional control method does.

Keywords： turbo-shaft engine control system hybrid control predictive control support vector machine

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Corresponding Authors: 张海波 Email: zh_zhhb@126.com

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