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直升机振动主动控制的机身/压电叠层作动器耦合优化法

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Coupled Fuselage/Piezoelectric Stack Actuator Optimization Method for Active Vibration Control of Helicopter

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摘要 直升机振动主动控制通常使用惯性作动器,一般惯性作动器的附加重量要占到机体重量的4%～5%才有较好的控制效果。压电叠层作动器(PSA)作为轻质、高效的执行元件用于直升机振动主动控制可有效地降低附加重量、提高控制性能。本文将压电叠层作动器用于直升机振动主动控制,并提出了机身/压电叠层作动器耦合优化法。采用基于频率响应函数的子结构法建立了直升机机身结构/压电叠层作动器的耦合频域方程,以最小化被控加速度响应为目标研究了压电叠层作动器的安装位置及控制器参数优化问题。采用实数编码遗传算法同时优化离散位置变量和连续控制加权参数变量,以得到在控制电压约束范围内的最有效振动抑制。对一个简化的弹性线机身模型进行了数值分析和时域控制仿真,结果表明所提方法能有效地找到最佳振动抑制参数,得到显著的振动抑制效果。

关键词: 直升机 压电叠层作动器 优化 振动主动控制 子结构法

Abstract: Inertial actuators are usually used in active vibration control of helicopter, additional weight of which generally has to account for 4%-5% of fuselage weight to achieve satisfactory control effect. This paper proposes the use of light-weight piezoelectric stack actuators (PSA) for active vibration control of helicopter to reduce additional weight, and presentes a coupled fuselage/piezoelectric stack actuator optimization method. By using the sub-structure method based on frequency response functions, the coupled helicopter fuselage structure/piezoelectric stack actuator frequency domain equations are established. Setting the minimization of controlled acceleration responses as the objective, the installation locations of piezoelectric stack actuators and controller parameter optimization are investigated. Real-coded genetic algorithms are used to simultaneously optimize the variables of discrete locations and continuous control weighting parameters so as to obtain the most effective vibration suppression in the constrained range of control voltages. Numerical analysis and control simulation in the time domain for an elastic line model of a helicopter fuselage are performed. The results indicate that the method presented in this paper can effectively find the optimal parameters of vibration control and achieve significant effect of vibration suppression.

Keywords: helicopters piezoelectric stack actuator optimization active vibration control sub-structure method

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