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旋翼翼型多目标多约束气动优化设计

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Multi-objective and Multi-constrained Optimization Design for a Helicopter Rotor Airfoil

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摘要 为了克服传统旋翼翼型优化设计方法的不足,发展了一种基于Kriging模型与遗传算法的旋翼翼型多目标多约束气动优化设计方法。采用基于雷诺平均Navier-Stokes方程的数值模拟获得样本翼型气动性能,并建立目标函数和状态函数的Kriging模型,采用遗传算法搜索Kriging模型最小值和相应的EI(Expected Improvement)函数最大值,更新Kriging 模型直至找到满足约束的最优翼型。运用加权目标函数法进行了旋翼翼型的多设计点优化设计。优化结果表明,优化后旋翼翼型在满足约束的同时,与基准旋翼翼型OA209相比:在悬停状态下,阻力系数下降了2.1%;在机动状态下,最大升力系数提高了4.2%;在前飞状态下,阻力系数在不同马赫数下均有所减小。

关键词： 旋翼翼型 Kriging模型 多目标 多约束 气动优化设计

Abstract： In order to overcome the drawbacks of the traditional optimization design method for a helicopter rotor airfoil, a multi-objective and multi-constrained aerodynamic optimization design method based on the genetic algorithm and the Kriging model is developed in this paper. Aerodynamic properties of the sample points are obtained by solving the Reynolds averaged Navier-Stokes equations, based on which the Kriging models of the objective functions and the state functions are created. Then, the points which have the minimum value of Kriging model and the maximum value of EI (Expected Improvement) function are searched by the genetic algorithm. The Kriging model is reconstructed by adding these new points. The above process is repeated until the global optimal solution is found. Combined with weighted sum of objective functions, the genetic algorithm is used for the helicopter rotor airfoils’ multi-objective and multi-constrained optimization design. The results show that while the optimized rotor airfoil meets the constraints, the drag coefficient is reduced by 2.1% in hover flight, and the maximum lift coefficient is increased by 4.2% in the maneuvering flight, compared with the baseline airfoil of OA209 airfoil. Besides, the drag coefficient is lower than that of the baseline airfoil in the forward flight at different Mach numbers.

Keywords： rotor airfoil Kriging model multi-objective multi-constraints aerodynamic optimization design

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