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基于近似技术的高亚声速运输机机翼气动/结构优化设计

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Multidisciplinary Aerodynamic/Structural Design Optimization for High Subsonic Transport Wing Using Approximation Technique

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摘要 探索基于近似技术的高亚声速运输机机翼气动/结构多学科设计优化方法,建立了基于近似技术的多学科设计优化框架。气动学科采用全速势方程加黏性修正进行翼身组合体跨声速流动的气动计算,结构学科采用有限元分析方法进行应力与变形计算。采用均匀设计法给出若干样本点,分别采用二次响应面、Kriging模型和径向基神经网络等多种近似技术,构造气动学科和结构学科的近似分析模型,并对几种近似模型精度进行了分析和比较。研究发现,Kriging模型和二次响应面具有几乎等同的较高的近似精度,神经网络的近似精度则较差,由于二次响应面计算量更小,故最终选定为机翼设计优化的近似方法。以升阻比和结构重量为目标,考虑升力、机翼面积以及应力和应变约束条件,对运输机机翼4个外形参数和4个结构参数进行多目标、多约束优化设计。优化后的机翼具有较好的气动/结构综合性能,表明本文方法是可行的。

关键词： 飞机设计 机翼 多学科设计优化 响应面 Kriging模型 神经网络 高亚声速运输机

Abstract: Multidisciplinary aerodynamic/structural design optimization is carried out for high subsonic transport wing using approximation technique. The framework of Multidisciplinary Design Optimization (MDO) based on approximation is presented and analyzed. The aerodynamic performance of wing-body combination in transonic flow is calculated with full-potential equation in conjunction with viscous correction method. Structural analysis is performed using finite element method to obtain stress and strain characteristics. The span, taper ratio, sweep angle and linear twist angle are chosen as design variables that define the aerodynamic configuration of the wing, and another four representing thicknesses of spars and skin are selected as the design variables for structural discipline. Uniform Design method is used to provide sample points, and approximation models for aerodynamic and structural discipline are constructed using quadratic response surface method (RSM), Kriging model (KM) and neutral networks (NN), respectively. The accuracy of each set of approximations is compared through numerical error analysis. The objective is to investigate whether KM and NN can construct more accurate global approximations than RSM in a real aerospace engineering application and finally choose that of best accuracy to be used in the present wing design optimization problem. It is found that KM and RSM have comparative high accuracies and both are more accurate than NN. Multi-objective optimization for the wing is performed based on RSM, with lift-to-drag ratio and weight as targets, and with lift, reference area, deform and equivalent stress as constraints. The optimum wing is proven to have better integrated performance and that the presented method is applicable in engineering for multidisciplinary aerodynamic/structural design optimization of high subsonic transport wing.

Keywords: aircraft design wing multidisciplinary design optimization response surface method Kriging model neural networks high subsonic transport

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