光学精密工程 » 2015, Vol. 23 » Issue (4): 1096-1104 DOI: 10.3788/OPE.20152304.1096

基于响应面法的微操作平台多目标优化

胡俊峰, 徐贵阳, 郝亚洲

江西理工大学 机电工程学院, 江西 赣州 341000

Multi-objective optimization of micro-manipulation stage based on response surface method

HU Jun-feng, XU Gui-yang, HAO Ya-zhou

School of Mechanical & Electrical Engineering, Jiangxi University of Science and Technology, Ganzhou 341000, China

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全文: PDF (1435 KB) RICH HTML NEW

输出: BibTeX | EndNote (RIS)

摘要 为了提高微操作平台的操作空间和动态性能, 基于响应面法对一种新型微操作平台进行了多目标优化设计。采用中心组合设计方法选取仿真试验点, 根据试验点建立平台的参数化几何模型, 应用软件ANSYS对平台进行静力学和模态分析得到其固有频率、位移放大倍数和最大应力的响应值。根据所得的仿真试验数据, 采用最小二乘法和显著性检验建立反映平台性能指标的二阶多项式响应面模型。最后, 计算了反映响应面拟合度的评价指标, 验证了所建响应面模型的精确性。以微操作平台的放大倍数和固有频率为优化目标, 强度为约束, 建立了平台的多目标优化模型, 采用多目标遗传算法对平台进行优化得到Pareto解集。从Pareto解集可知, 固有频率与放大倍数之间是相互冲突的, 故需权衡固有频率和放大倍数从Pareto解集选取最优解。比较优化前后平台的各性能指标可知, 平台的固有频率增大了35.58 %, 放大倍数增大了2.33 %, 最大应力减小了38.97 %, 证明了提出的优化方法的有效性。

关键词 : 微操作平台, 中心组合设计, 响应面法, 多目标遗传算法

Abstract : To improve the operating space and dynamic characteristics of micro-manipulation stages, the multi-objective optimization design was performed for a new micro-manipulation stage based on response surface method. The central composite design method was used to select test points and the parametric geometric modeling of the stage was built based on the test points. The software ANSYS was uesd to carry out statics and modal analysis to obtain the response values of natural frequency, displacement amplification ratio and the maximum stress of the stage. Then, the least square method and the test of significance were employed to build the two-order polynomial response surface model to reflect the performance index of the stage according to the simulation test data. The evaluation indexes reflecting fitting degree of the response surface were calculated to illustrate the veracity of the proposed response surface model. Furthermore, a multi-objective optimization model of micro-manipulation stage was established by taking the displacement magnification and the natural frequency as object functions, the strength as the constraint. The multi-objective genetic algorithm was taken to obtain Pareto solution set. The Pareto solution show that the natural frequency is in conflict with amplification ratio of the stage, so the optimal solution is chosen from Pareto set by weighing the natural frequency and amplification ratio. The comparative analysis of the performance indexes of the stage before and after optimizations shows that the natural frequency and the magnification ratio increase by 35.58 % and 2.33 %, respectively, and the maximum stress decreases by 38.97 %. It illustrate that the proposed optimization method is effective.

Key words : micro-manipulation stage central composite design response surface method multi-objective genetic algorithm

收稿日期: 2014-09-20

中图分类号: TH703

TP274

基金资助:国家自然科学基金资助项目(No. 51265016);江西省自然科学基金资助项目(No.20122BAB216029);江西理工大学科研基金资助项目(No.jxxj12050)

作者简介: 胡俊峰(1978-),男,江西临川人,博士,副教授,2010年于华南理工大学获得博士学位,主要从事柔顺机构及振动控制方面的研究。E-mail:hjfsuper@126.com;徐贵阳(1991-),男,江西九江人,硕士研究生,2012年于江西理工大学获学士学位,主要从事柔顺机构方面的研究。E-mail:xuguiyang911009@sina.com

引用本文:

胡俊峰, 徐贵阳, 郝亚洲. 基于响应面法的微操作平台多目标优化[J]. 光学精密工程, 2015, 23(4): 1096-1104. HU Jun-feng, XU Gui-yang, HAO Ya-zhou. Multi-objective optimization of micro-manipulation stage based on response surface method. Editorial Office of Optics and Precision Engineering, 2015, 23(4): 1096-1104.

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