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微纳技术与精密机械

微纳测量机测头弹性结构的参数设计

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摘要: 根据微纳米三坐标测量机对测头各项指标的要求, 提出了4种测头弹性结构的设计方案。通过力学分析建立测头弹性结构三维刚度模型, 应用有限元分析软件ANSYS分别对4种弹性结构的刚度进行仿真计算; 然后, 分析讨论了4种弹性结构的性能特点。综合考虑测量刚度、灵敏度及结构紧凑稳定等多种因素, 选择十字型结构作为微纳米测量机测头的弹性结构, 并对其进行了结构参数的优化和测头刚度各向同性设计。搭建了高精度三维位移测试平台, 对测头的测量范围、线性、位移误差进行了实验验证。仿真分析和实验结果表明, 测头的弹性结构满足测量范围 $40\ \mu\text{m}\times 40\ \mu\text{m}\times 20\ \mu\text{m}$ 、测量刚度小于 $0.5\ \text{mN}/\mu\text{m}$ 及刚度各向同性的要求, 整体测量误差小于 $100\ \text{nm}$ 。

关键词: 三坐标测量机 微纳米测量 接触扫描测头 弹性结构设计 有限元分析

Design Elastic Structure Parameters of probe in micro-nano CMM

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Abstract: According to the isotropic requirements of micro-nano Coordinate Measuring Machines(CMMs) for a probe, four kinds of elastic structure design schemes for the probe were proposed. A three-dimensional stiffness model of elastic structure was established by mechanical analysis. The stiffnesses of four elastic structures were simulated by using finite element analysis software ANSYS, and the performance characteristics of the four structures were analyzed and discussed. In consideration of a variety of factors like measuring stiffnesses, sensitivity and stable compact structures, a cross shape structure was selected as the elastic structure of micro-nano CMM probe, and its structure parameters were optimized and stiffness isotropic was designed. A high precision three-dimensional micro displacement test platform was set, and the measuring range, linearity and displacement error of the probe were tested and verified by experiments. Simulation and experiment results show that the elastic structure of the probe meets the requirement of a measuring range of $40\ \mu\text{m}\times 40\ \mu\text{m}\times 20\ \mu\text{m}$, stiffness less than $0.5\ \text{mN}/\mu\text{m}$ and stiffness isotropic, and its overall measurement error is less than $100\ \text{nm}$.

Keywords: coordinate measuring machine (CMM) micro and nano measurement contact scanning probe elastic structure design Finite Element Analysis(FEA)

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