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一种基于超导的重力梯度敏感结构分析

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Analysis of Sensing Mechanism for Gravity Gradient Based on Superconductivity

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摘要 为了构建小型化全张量重力梯度测量系统,提出一种轴向分量与交叉分量同时敏感的基于超导的重力梯度敏感结构。基于螺旋理论分析两分量敏感结构的自由度,利用自由空间的运动螺旋系与互逆原理得到约束螺旋系,进一步得到具有冗余约束的对称约束构型,并选择柔性元件构建并联机构形式的两分量敏感结构,利用柔性虎克铰的横向与竖向柔性铰链实现等效球铰的功能。然后分析转臂质量沿轴移动与绕轴转动时柔性元件的变形,根据几何关系与功能定理得出两分量敏感结构的沿轴移动刚度与绕轴转动刚度。通过实际参数的计算,明确了各参数对结构刚度的影响,仿真结果验证了分析过程的准确性。

关键词： 超导   重力梯度   自由度分析   刚度分析   螺旋理论

Abstract： In order to measure the whole range of components of a gravity gradient with a miniaturized system, a simultaneous sensing mechanism of both the inline and cross components is presented. Based on the screw theory, the freedoms of the sensing mechanism of the superconductor gravity gradient are analyzed. The wrench of the free space and reciprocity of the screw theory are adopted to obtain the twists to express constraints. One symmetry type mechanism with redundancy constraints is deduced, which can be built by flexible elements according to a parallel mechanism form. Based on the transverse and vertical flexible hinges of flexible Hooke hinge, the function of equivalent spherical hinge can be realized. The deformation of the flexible elements is analyzed when the pivoted arm moves along the axial direction or rotates around the same axis. According to the geometrical relationship and the principle of conservation of energy, the axial rigidity and rotational stiffness are deduced. By means of finite element simulation, it can be concluded that the stiffness of the designed motion is influenced by the parameters of the mechanism. The simulation results verify the analysis process.

Keywords： superconductor   gravity gradient   freedom analysis   stiffness analysis   screw theory

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