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全柔性微型机构的拓扑优化设计技术研究

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Fully Compliant Micro-mechanism Using Topological Optimization Approach

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摘要 提出一种全柔性机构拓扑优化设计的新方法。用折衷规划法建立了柔性机构的多目标优化设计模型,在优化目标中引入运动学函数和结构函数分别表示柔性机构设计对机构柔性和结构刚度的要求,并采用伴随敏度分析法进行优化设计的敏度分析。将传统凸规划方法中的移动渐近线方法(MMA)推广到连续体的结构拓扑优化设计中,并形成一种新的具有全局收敛特点的移动渐近线方法(GCMMA)。对柔性机构拓扑优化设计中出现的数值计算困难问题进行了分析和研究,并提出一种改进的SIMP密度-刚度插值模型,该模型能有效消除机构中出现的棋盘格式和网格依赖性,并能明显减弱单点铰链连接问题。通过典型算例证明了本文方法的有效性,并对算例结果进行了快速原型制造。

关键词： 柔性机构 拓扑优化 多目标优化 移动渐近线方法 密度过滤技术

Abstract： This work presents a new methodology for fully compliant micro-mechanism design using continuum topological optimization method. The multi-objective optimization model is established by using compromise programming scheme, in which a kinematical function and a structural function are both applied to indicate the demands of mechanism flexibility and structure stiffness, and the sensitivities for compliant mechanism optimization design is performed by adopting the adjoint sensitivity analysis method. A new globally convergent method of moving asymptotes (GCMMA) is worked out based on the method of moving asymptotes (MMA) belonging to convex programming methods. Numerical instabilities occurring in resulting mechanism are also investigated and a modified SIMP density-stiffness interpolation scheme is suggested not only to eliminate checkerboards and mesh-dependency, but also to improve the one-node connected hinges. The typical application, a micro inverter mechanism, is employed to demonstrate the validation of the algorithms presented in this work. A procedure has been suggested to convert the topological optimization results to a CAD model, and the prototype has also been fabricated as the proof of concept design by laser manufacturing technology.

Keywords： compliant mechanism topological optimization multi-objective optimization the method of moving asymptotes density filtering approach

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