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固体力学与飞行器设计

压力载荷下的结构拓扑-形状协同优化

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Simultaneous Topology and Shape Optimization of Pressure Loaded Structures

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摘要 压力载荷作用下的结构轻量化设计是工程中的常见问题，由于压力加载面的可设计性，现有以固定载荷为基础的拓扑优化技术不能很好地处理这类问题。直接采用CAD参数化样条或B样条曲线描述压力加载面，通过拓扑和形状变量的联合优化满足了工程实际对结构轻量化与边界的功能性与光滑性设计要求。同时，为了避免结构边界形状变化时有限元网格刷新引起的定义拓扑伪密度变量的困难，用所提出的背景网格和密度点技术实现了每一步单元密度设计迭代结果的自动传递，并采用网格变形技术实现了形状设计变量灵敏度分析。采用4个数值算例验证了方法的有效性，其中发动机承力框架的设计结果充分说明该方法在航空结构设计中的重要应用价值。

关键词： 拓扑优化 形状优化 压力载荷 轻量化设计 背景网格

Abstract： It is common practice in engineering design to carry out lightweight structural optimization under pressure load. As the loaded boundary is designable, existing topology optimization techniques related to fixed loads are unable to deal with this kind of problem. In this article, CAD parametric splines or B-splines are used directly to represent the pressure loaded surface. A simultaneous topology and shape optimization method is proposed to ensure that the structure achieves lightweight, functionality and smoothness of the boundary shape needed in practice. Likewise, background grid and density point techniques are developed to favor the definition of topology pseudo density variables when the mesh updating is made along with the boundary variation of the structure. This makes it possible to ensure an automatic transfer of material density results from one mesh to another after each iteration. Meanwhile, shape sensitivity analysis is made available using the mesh morphing scheme. Four numerical examples are presented to demonstrate the validity of the proposed method. The design solution of an aero-engine support highlights the importance of the method in aeronautical applications.

Keywords： topology optimization shape optimization pressure load lightweight design background grid

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