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周期性结构热动力时间-空间多尺度分析

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摘要 研究一种时间-空间多尺度渐近均匀化分析方法，模拟不同的极端热和动力载荷下微尺度多相周期性结构中热动力响应问题，并建立一个广义的波动函数场控制方程描述热动力响应. 通过引入一个放大空间尺度和两个缩小时间尺度，在不同时间尺度上获得由空间非均匀性引起的波动效应和非局部效应. 根据高阶均匀化理论在空间和时间上进行均匀化，获得高阶非局部函数场波动方程. 并进一步用C0连续修正了高阶非局部函数场波动方程的有限元近似解，使问题的求解避免了对有限元离散的C1连续性要求. 并与经典的空间均匀化方法相比较，指出了经典的空间均匀化方法的局限性，进一步以一维非傅立叶热传导和热动力问题为例，讨论了各种情况下方法的正确性与有效性.

关键词 多尺度方法,均匀化方法,热动力,非傅立叶热传导,高阶非局部模型

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Thermodynamic analysis of multiphase periodic structures based on a spatial and temporal multiple scale method

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Abstract

A spatial and temporal multiscale asymptotic homogenization method simulating the wave propagation problem in periodic multiphase materials is systematically studied. Generalized function field governing equations of wave propagation are expressed in a unified form with both inertia and velocity items. Amplified spatial and reduced temporal scales are, respectively, introduced to account for spatial and temporal fluctuations and nonlocal effect of the homogenized solution due to material heterogeneity on different time scales. The model is derived from the higher-order homogenization theory with multiple spatial and temporal scales. By combining various orders of homogenized function field equations, the reduced time dependence is eliminated and then the fourth-order differential equations are derived. To avoid the necessity of C1-continuity in finite element implementation, the C0-continuous mixed finite element approximation of the resulting nonlocal equations of function field is put forward. Non-Fourier heat conduction and thermal dynamic problem are computed to demonstrate the efficiency and validity of the theories and models developed and indicate the disadvantages of the classical spatial homogenization.

Key words thermodynamic non-Fourier heat conduction multi-scale method homogenization high-order nonlocal model

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