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材料非线性微-宏观分析的多尺度方法研究

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摘要　介绍并比较了近年来在材料非线性微-宏观分析多级数值方法方面的研究工作. 针对考虑材料内摩擦接触的颗粒材料多尺度计算问题，建立一种基于数值技术的多级分析方法. 方法的特点是在对材料进行微观分析的基础上建立宏观材料的多尺度非线性数值本构模型. 而对材料弹塑性多级分析问题，建立了基于转换场技术的算法，采用近似技术建立非线性分析的本征应变矩阵，使方法具有表达简单与实现方便的特点. 给出了数值算例，通过比较说明了方法的正确性与有效性.

关键词　复合材料,多尺度分析,均匀化方法,弹塑性,数值方法

分类号

Multiscale Methods For Nonlinear Analysis Of Composite Materials

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Abstract

A composite material is called spatially periodic if it is possible to be decomposed into elementary components or cells of periodicity. The characteristic size of the single cell of periodicity is assumed much smaller than the geometrical dimensions of the structure which is therefore composed of a large number of cells. The great achievements have been obtained from the research of homogenization algorithm based on the elastic assumption. Because the failure process of material is generally related to the nonlinear analysis of the materials, the research work on the multi-scale analysis of the nonlinear behaviors of the materials is more significant for engineering applications. However, due to the difficulties of the solving of nonlinear problems, the research work will be more complex and more difficult than those performed for the elastic homogenization analysis. The numerical approach in the paper differs somewhat from those proposed in previous studies. For micro-macro analysis of periodic material composed of elastic granules with contact characteristics, this paper adopts the method which was developed by the first author. The basic principle of the method is based on the numerical constitutive model. The important features of developed algorithm are that during the process of establishing macroscopic constitutive law the stick-disengage-slip behaviors in the granular contact interfaces are taken into account. Different from the pure contact problem, the stick relationship considers initial stick cohesion between the granules when the sticking state is destroyed (the material will thus proceed a damaged state). For the micro-macroscopic analysis of multi-phase elastic-plastic materials, according to transformation field theory, a consistent algorithm for elastic-plastic material analysis on micro-macroscopic is proposed. The basic theories for the establishing of the numerical method are introduced first in the paper, and then the numerical technique is described in detail. Finally, the numerical example is presented to demonstrate the validity and efficiency of the two algorithms.

Key words　composite material　multiscale analysis　homogenization method　elasto-plasticity　numerical method

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