地球物理学报 » 2012, Vol. 55 » Issue (12) :4239-4248 doi:10.6038/j.issn.0001-5733.2012.12.035

引用本文(Citation):
刘善琪, 李永兵, 田会全, 刘旭耀, 朱伯靖, 石耀霖.含湿孔隙岩石有效热导率的数值分析. 地球物理学报, 2012,55(12): 4239-4248,doi: 10.6038/j.issn.0001-5733.2012.12.035

LIU Shan-Qi, LI Yong-Bing, TIAN Hui-Quan, LIU Xu-Yao, ZHU Bo-Jing, SHI Yao-Lin.Numerical simulation on thermal conductivity of wet porous rock.Chinese J.Geophys. (in Chinese),2012,55(12): 4239-4248,doi: 10.6038/j.issn.0001-5733.2012.12.035

含湿孔隙岩石有效热导率的数值分析

刘善琪, 李永兵, 田会全, 刘旭耀, 朱伯靖, 石耀霖*

中国科学院计算地球动力学重点实验室,中国科学院大学,北京 100049

Numerical simulation on thermal conductivity of wet porous rock

LIU Shan-Qi, LI Yong-Bing, TIAN Hui-Quan, LIU Xu-Yao, ZHU Bo-Jing, SHI Yao-Lin*

Key Laboratory of Computational Geodynamics, CAS, University of Chinese Academy of Sciences, Beijing 100049,China

摘要

本文采用有限元方法研究含湿孔隙岩石的有效热导率,即随机划分网格并指定材料性质,建立三维含湿孔隙岩石的有限元模型,模型的上下表面施加不同的温度,侧面绝热,计算出总热流,然后结合上下表面的温度梯度计算出岩石的有效热导率.考虑到单个随机模型不一定具有代表性,对给定的孔隙率和饱和度均生成了200种矿物、水、空气随机分布的岩石模型,进行Monte Carlo实验和统计分析,统计分析结果与前人实验结果吻合良好.数值分析结果表明,孔隙岩石的有效热导率与岩石的孔隙率、饱和度、固体矿物组分及孔隙的分布情况有关,数值计算的误差随着网格数目的增加而减小.此有限元方法可以用来估算岩石的有效热导率,在已知组分性质的多矿物岩石物性计算方面有广阔应用前景.

关键词 有限元, 多孔介质, 孔隙岩石, 有效热导率, 数值模拟

Abstract:

This paper presents a numerical simulation method to study thermal conductivity of wet porous rock. First, a three-dimensional digital physic model is established by randomly partitioning the rock model and assigning different materials to sub-partitions. Numerical model is in the shape of a cylinder. We impose different temperatures as boundary conditions on the upper and lower surface. The cylindrical surface is adiabatic. The heat flux is obtained by the finite element method, then the effective thermal conductivity of the rock is calculated by combining with the temperature gradient. For a certain porosity and degree of saturation, we adopt an elaborately designed Monte Carlo method to meet the requirement of the random characteristics of grain size, pore space and spatial distribution. Compared with the experimental data, the present model can give fine predictions of the effective thermal conductivity of wet porous rock. We find that the effective thermal properties of the porous rock depends on the type of minerals, the porosity, the degree of saturation and the distribution of pores. The numerical error decreases with the increasing number of grids. This finite element method can be used to compute the effective thermal conductivity and other physical properties of minerals with known components.

Keywords Finite element, Porous media, Porous rock, Effective thermal conductivity, Numerical simulation

Received 2012-04-28;

Fund:

地壳深部探测专项(SinoProbe-07),国家自然科学基金(41174067)和国家科技支撑计划项目(2011BAB03B09)资助.

Corresponding Authors: 李永兵,男,1973年生,副教授,硕士生导师,矿物学、岩石学、矿床学专业.E-mail:yongbingli@gucas.ac.cn Email: yongbingli@gucas.ac.cn

About author: 刘善琪,女,1987年生,固体地球物理学专业硕士研究生.E-mail:liushanqi10@mails.gucas.ac.cn