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深部岩体非线性Kelvin蠕变变形的混沌行为

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摘要　　随着矿山开采的大规模进行和采深的加大，在深部高应力作用下巷道围岩的破坏日益严重，这使得越来越多的采用非线性科学理论和方法分析巷道围岩的稳定性。推导非线性Kelvin流变模型的本构方程以及其蠕变曲线的解析解；分别采用两种数值微分方法对非线性蠕变方程进行求解，结果发现非线性蠕变方程的数值解在有些情况下与解析解不一致，即数值解可能出现不稳定；通过变量代换，该非线性蠕变方程可化为Logistic方程。这样，通过将岩体的本构模型与非线性理论相结合，从理论上证明岩体的非线性蠕变具有混沌行为，并相应获得岩体变形发生混沌的条件，根据实测位移序列，为采用混沌学方法进行深部岩体工程的稳定性预测和控制奠定理论基础。

关键词　　岩石力学　深部岩体　混沌　非线性Kelvin体　蠕变　Logistic方程

分类号

CHAOTIC BEHAVIOR OF NONLINEAR KELVIN CREEP OF ROCK MASS IN DEEP GROUND

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Abstract

With the large-scale exploitation and deep mining，the breaking of rock roadways under high stress becomes very serious. So，the stability of rock roadways is increasingly analysed by using the theories and methods of nonlinear sciences. In this paper，the constitutive equation of the nonlinear Kelvin¢s rheological model in uniaxial stress is derived；and the analytical solution of its creep curve is developed. Then，the nonlinear creep equation is solved by two numerical differential methods respectively. It is found that the numerical solutions of the nonlinear creep equation are different from the analytical solutions in some conditions；in other words，the numerical solutions may be instable. And by using variable substitution，the nonlinear creep equation can become of the Logistic equation. Thus，it theoretically shows that chaos occurs in the nonlinear creep deformation of rock mass；and the condition is obtained in which the chaotic behavior of rock mass happen. Therefore，based on a practical displacement time series，the theoretic basis is given to predict and to control the stability of rock mass engineering in deep ground，by using the chaotic method.

Key words　rock mechanics　rock mass in deep ground　chaos　nonlinear Kelvin body　creep　Logistic equation

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