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动静组合加载下岩石破坏的应变能密度准则及突变理论分析

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摘要　阐述了岩石在动静组合载荷作用下使用应变能密度定义破坏准则的适用性。分析认为，岩石破坏的应变能密度的临界值与岩石破坏之前的不可逆变形过程和外界条件有关，而不可逆变形过程主要是由于岩石的非弹性变形、损伤和其他内部耗散机制引起的，且反映静水压力的体积变形能在某些应力状态条件下的岩石破坏中是不能忽略的。提出用机械模型来反映动静组合加载下岩石单元体弹性的劣化和非弹性变形的产生以及加载速率的影响，并以机械模型为基础，求出受一维静载岩石在动载作用下破坏应变能密度的临界值。同时，根据静力预加载结构的冲击屈曲突变模型，建立了静加载岩石系统的冲击破坏模型，进一步分析了动静组合加载下岩石的破坏。最后，采用低周疲劳加载方法在Instron电液伺服控制材料试验机上进行了红砂岩中应变率下的动静组合加载破坏试验，对应变能密度准则和突变理论模型进行了验证。结果表明，理论模型与试验结果有较好的一致性。

关键词　岩石力学；动静组合加载,应变能密度；破坏准则；中应变率；低周疲劳加载

分类号

FAILURE CRITERION OF STRAIN ENERGY DENSITY AND CATASTROPHE THEORY ANALYSIS OF ROCK SUBJECTED TO STATIC-DYNAMIC COUPLING LOADING

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Abstract

The applicability of a failure criterion for the strain energy density of rock under static-dynamic loading is proposed. According to the analysis，critical value of strain energy density of rock is mainly determined by preceding irreversible deformation process and current environmental state；and the irreversible deformation is mainly caused by nonelastic deformation，damage and other possible intrinsic dissipative mechanisms of rock in a mechanical system；and volume deformation energy associated with hydrostatic stress effects can not be neglected on some stress states. Using mechanical model to represent the reduction of elasticity，occurrence of inelasticity deformation and effect of loading rate are proposed. On the basis of mechanical model，the critical value of strain energy density of rock under static-dynamic loading is derived. According to the catastrophe model for impact buckling of static-loading structures，a new catastrophe model for impact disturbance fragmentation of a rock system under static loading is established to analyze the rock failure under static-dynamic coupling loading ulteriorly. Finally，by using of the Instron electro-hydraulic and servo-controlled material testing machine and adopting low-cycle-index fatigue loading method，the test of red sandstone failure with medium strain rate under dynamic loading is carried out to verify the strain energy density criterion and catastrophe theory model. There is a good agreement between theoretic and experimental results.

Key words rock mechanics；static-dynamic coupling loading；strain energy density；failure criterion；medium strain rate；low-cycle-index

fatigue loading

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