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三维裂纹应力强度因子数值计算

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摘要　利用无网格Galerkin方法对三维裂纹问题进行分析。基于最小二乘法的无网格方法仅需一系列节点信息就可构成物体的离散模型。在无网格Galerkin方法中，位移边界条件不包含在内，因此，在边界已知位移方向上设置一系列弹簧来满足无网格方法的本征边界条件。弹簧的一端与已知位移的物体表面固连，而另一端固定，把计算位移与已知位移的误差作为弹簧的变形量。弹簧作为弹性体的一部分，弹簧的变性能也是弹性体应变能的一部分。裂纹使得弹性体具有不连续性，对体内节点具有隔离作用。用可视准则处理裂纹面对影响域内Gauss点的隔离作用。提出简单有效的方案，确定可变的节点影响域，这一方案可以保证体内每一个节点影响域内的节点数为一给定的常数，通过限制影响域内最小二乘计算的大小，提高计算近似函数的效率。利用三维间断位移法计算三维裂纹前缘的应力强度因子，计算有限体内边界贯穿平置裂纹和边界非贯穿平置裂纹的应力强度因子。无网格Galerkin方法的计算结果与前人研究的结果吻合很好，这可为三维裂纹的扩展追踪提供参考。

关键词　岩土力学；应力强度因子；三维裂纹；可视准则；三维间断位移法；扩展的无网格方法

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NUMERAL CALCULATION OF THREE-DIMENSIONAL CRACK STRESS INTENSITY FACTOR

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Abstract

The application of element-free Galerkin(EFG) method to problems in three-dimensional fracture problems is presented. The EFG method is based on moving least square(MLS) approximations，and only a set of nodal points and a description of the body are employed to formulate the discrete model. In the EFG method，displacement boundary conditions are not included directly，so along the orientation of displacement known on boundary or surface，a set of springs to implement the essential

boundary conditions are assumed. One side of the spring links together with the boundary or surface known displacement，and the other one is fixed. The mistake between calculating displacement and known displacement is regarded as transmutation of spring. The spring is a part of the body，so the potential energy is a part of strain energy of body. The crack causes discontinuity of the body. It has isolation effect on nodal points. The isolation effect of cracks on domain of influence for Gauss points is dealt by the application of visibility criterion. A simple and efficient scheme is proposed to define the variable domain of nodal points influence. The scheme deems that the number of nodal points is constant and visible from each domain of influence. This method significantly increases the efficiency of computing approximate functions by limiting the size of the least-square problem. Three-dimensional discontinuous displacement method is used to evaluate stress intensity factors along the 3D crack front. Applications of the method to the determination of stress intensity factors along single edge planar cracks and single through edge planar crack in 3D finite bodies are presented. The obtained stress intensity factors for both problems are found to be in good agreement with SIF values reported in previous studies. It can guarantee the success for trace propagation of three-dimensional crack.

Key words rock and soil mechanics；stress intensity factor；three-dimensional crack；visibility criterion；three-dimensional discontinuous displacement method；enriched element-free Galerkin method

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