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渗透水压作用下类岩石材料张开型裂纹启裂特性研究

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CRACK INITIATION CHARACTERISTICS OF OPENING-MODE CRACK EMBEDDED IN ROCK-LIKE MATERIAL UNDER SEEPAGE PRESSURE

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摘要 在探讨渗透水压和远场应力共同作用下张开型裂纹的启裂规律及裂纹尖端应力强度因子的演化规律的基础上，建立压剪应力场和渗流场共同作用下含预置裂纹类岩石材料的损伤断裂力学模型和裂纹尖端应力强度因子演化方程，提出运用裂纹尖端应力强度因子作为判断压剪岩石裂纹的启裂准则。研究结果表明：张开型裂纹尖端应力强度因子受围压、渗透水压力、裂纹尖端曲率半径以及裂纹倾角等因素的影响；裂纹启裂角随预制裂纹角度的变化不大，其值约为70.5°；裂纹启裂强度与渗透水压力、裂纹长度、裂纹尖端曲率半径成反比，与围压的大小成正比，此外还与裂纹倾角有关。算例验证表明，运用不同的断裂判断准则均可得出岩石裂纹初裂强度随渗透水压力的增大而呈减小的趋势。且进一步的试验也验证了启裂强度与渗透水压成反比而与围压成正比；当裂隙角度为30°时裂纹启裂强度最大，60°次之，45°最小。提高渗透水压可显著降低张开型裂纹的启裂强度，这一结果可为深部高应力岩体诱导破裂提供新的思路。

关键词： 岩石力学 渗透水压力 张开型裂纹 应力强度因子 裂纹启裂 断裂破坏准则

Abstract： The law of opening-mode crack initiation and the evolution of crack tip stress intensity factor were detected considering the combined action of seepage pressure and far-field stress. Accordingly，the damage fracture mechanical model of rock-like material and the evolution equation of the crack tip stress intensity factor were proposed for pre-cracking rocks under the combined actions of compression-shear field and seepage field. The crack tip stress intensity factor was advised to be used as a criterion for judging the degree of rock crack initiation. The results show that：(1) Open crack tip stress intensity factor is influenced by confining pressure，seepage pressure，crack tip radius of curvature，as well as crack inclination angle. (2) Little change is observed in the cracking angle，which maintains about 70.5° with the pre-crack angle varying. (3) The cracking strength is inverse proportion to the seepage pressure，crack length and the crack tip radius of curvature，while in direct proportion to the confining pressure. Also the crack angle is responsible for the crack strength. The case studies indicate that the uses of different crack initiation criteria all lead to an identical tendency that the crack initiation strength decreases with the increase of the seepage pressure. The laws that the crack initiation strength is inverse proportion to the seepage pressure and proportion to confining pressure are further verified by conducting experiments under various experiments. When the crack angle is 30°，the crack initiation strength is maximal，the crack angle of 60° next and 45° last. It is worthwhile to pay attention to the fact that increasing the seepage pressure would result in the decrease of the crack initiation strength，enlightening the prospect of easier ore extraction under high stress by hydraulically induced cracking.

Keywords： rock mechanics seepage pressure opening-mode crack stress intensity factor crack initiation fracture failure criteria