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考虑岩石疲劳损伤的空气冲旋钻井破岩数值模拟研究

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NUMERICAL ANALYSIS OF AIR HAMMER BIT DRILLING BASED ON ROCK FATIGUE MODEL

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摘要 以川东北PGP-X井为研究对象，对2 140～4 914 m地层进行分段采样，运用静态试验机和分离式霍普金森压杆(SHPB)试验装置对采样岩石进行动、静态力学性能室内试验。利用LS-DYNA建立空气冲旋钻井活塞－钻头－岩石相互作用系统模型，仿真模型中岩石采用H-J-C动态本构，为考虑冲击载荷往复加载对岩石造成的损伤积累，在每次冲击后，对井底岩石进行强度修正。在此基础上，研究PGP-X井钻井参量及空气锤结构参量与冲击功及破岩比功的关系，探索冲击功、冲击末速度、钻压、冲击频率、转速、井深及岩性对破岩能效的影响。分析发现冲击功－破岩比功曲线具有界限明显的波动区与稳定区，由此得到空气冲旋钻井的临界冲击功及临界钻压；临界冲击功及临界钻压与井深和岩性密切相关，随着井深和岩石硬度增加，临界冲击功和临界钻压都有逐渐减小。通过以上研究，推荐了典型深部地层的临界冲击功、临界钻压、最佳转速与冲击频率组合，这些结果可以作为现场空气冲旋钻井实践的参考。

关键词： 岩石力学 空气冲旋钻井 岩石疲劳损伤 岩石动态本构关系 钻井参数 破岩比功

Abstract： Taking PGP-X well located in Northeast Sichuan province as the research object，the rocks have been sampled respectively between depths of 2 140－4 914 m. Laboratory experiments of static and dynamic mechanical properties of the sampled rocks are performed with the split Hopkinson pressure bar(SHPB)and material test system. By using LS-DYNA，piston-drilling bit-rock interaction system model for air hammer bit drilling is established. In the simulation model，H-J-C dynamic constitutive model is adopted for rock. Taking the damage accumulation caused by the repeated impulsive load into consideration，rock intensity at well bottom is modified after being impacted every time. On this foundation，drilling parameters，structure parameters of air hammer，and the relationship between impact energy and crushing work ratio are researched；and the influences of impact energy，final impacting speed，drilling pressure，impact frequency，rotary speed，well depth and lithologic characters on rock crushing efficiency are explored. The analysis results show that the impact energy-crushing work ratio curve has fluctuation zones and stable zones with clear boundary，so that the critical impact energy and critical drilling pressure of air hammer bit drilling can be obtained. Further research indicates that the critical impact energy and critical drilling pressure are closely related with well depth and lithologic character. With the increase of well depth and rock hardness，both critical impact energy and critical drilling pressure have a tendency of gradually declining. After the simulation of air hammer bit drilling in different formations and lithologies，combinations of critical impact energy，critical drilling pressure，the best rotary speed and impact frequency in typical deep formations are recommended. These results can be for references in field practices for air hammer bit drilling.

Keywords： rock mechanics air hammer bit drilling rock fatigue rock dynamic constitutive relations drilling parameters

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