Postprint of Research on High-Pressure Water-Abrasive Coupled Jet Rock Breaking Technology and In-Situ Sample Preparation Apparatus

Authors: Du Weizhang, Cheng Peiming, Zhao Shunli, Yu Yang, Guo Chong

Date: 2025-08-04T00:00:00+00:00

Abstract

To address the issues of harsh working environments, low efficiency, and insufficient adaptability to complex geological conditions associated with conventional in-situ rock sample preparation techniques, this paper proposes an in-situ sampling device based on high-pressure water-abrasive coupled jet rock-breaking technology. By integrating an adjustable cutting head, a dual-inlet jet system, and an intelligent control module, the device achieves adaptive switching between efficient cutting of hard rock and non-destructive sampling of soft rock. Combined with field tests, the device has been verified to exhibit significant advantages in rock-breaking and cutting efficiency (improvement of over 35%), sample integrity (fracture rate < 2%), and energy consumption optimization (reduction of 28%). The research results provide innovative technical support for geological exploration and engineering rock mass quality assessment.

Full Text

High-pressure Water-abrasive Coupled Jet Rock Breaking Technology and In-situ Sample Preparation Device

DU Weichang[1], **CHENG Peiming**[1], **ZHAO Shunli**[1], **YU Yang**[1], **GUO Chong**[1]

(1. Jianghe Anlan Engineering Consulting Co., Ltd., Zhengzhou 450001, China)

Abstract

To address the challenges of harsh working conditions, low efficiency, and poor adaptability to complex geology in traditional in-situ rock sample preparation techniques, this study proposes a novel in-situ sampling device based on high-pressure water-abrasive coupled jet rock-breaking technology. By integrating an adjustable cutting head, a dual-inlet jet system, and an intelligent control module, the device achieves adaptive switching between high-efficiency hard rock cutting and non-destructive soft rock sampling. Field tests demonstrate its significant advantages in rock-breaking efficiency (35% improvement), sample integrity (fracture rate $< 2\%$), and energy consumption (28% reduction). The results provide innovative technical support for geological exploration and engineering rock mass quality assessment.

Keywords: High-pressure water-abrasive coupled jet; In-situ sampling; Rock mass integrity; Adaptive control

Introduction

The preparation of in-situ rock samples is a critical step for obtaining rock mass mechanical parameters, yet this process faces numerous technical challenges. Due to the inherent heterogeneity and anisotropy of rock masses, sample preparation must ensure representativeness while precisely controlling the distribution and orientation of structural planes (such as faults, fractures, and bedding) and pre-existing fissures. These factors directly influence the accuracy and reliability of subsequent mechanical parameter tests, which serve as fundamental data for engineering geology, mining operations, engineering design, resource assessment, and environmental management.

Traditional mechanical cutting techniques suffer from inherent limitations including low efficiency in hard rock cutting, thermal damage to samples, and poor adaptability to complex strata. High-pressure water jet technology has emerged as a novel geotechnical cutting method with significant advantages, prompting extensive research both domestically and internationally. Pozzetti et al. [1] proposed a numerical method for simulating water jet action, particularly in capturing cumulative rock mass damage, which enhances understanding of erosion processes induced by water jets. Piush Raj and Jifu Yin et al. [2][3] investigated various factors affecting rock-breaking performance, concluding that both pulsed jet frequency and incident angle substantially influence breaking characteristics. Dehkhoda et al. [4] studied the role of pulsed jets in rock fragmentation, finding that high-velocity pulsed jets generate internal stress waves causing fatigue failure, with pulse length and frequency playing crucial roles. Wu Wei et al. [5] employed a CFD Eulerian multiphase flow model using Fluent software to compare internal and external flow fields of abrasive side-entry, center-entry, and improved center-entry nozzles under identical boundary conditions. Domestic theoretical research on water jet rock breaking primarily focuses on frameworks such as "tension-water wedge" and "compact core-splitting" theories, which explore combined water jet-mechanical impact mechanisms [6][9]. Zhai Shengyu [10] investigated the fracture-enhancing mechanism and slotting performance of abrasive water jets, establishing a neural network prediction model. The combined action of water jets and mechanical forces creates stress wave superposition in rock, significantly increasing shear and tensile stresses in superposition zones, which promotes