Conference track «Oil and Gas Field Development»

Thermo-Mechanical Coupling Behavior on Shale: Insights from Real-time High-temperature Triaxial Compression Experiments

Научный руководитель – Александровна Моторова Ксения

Wang Yahua
Doctor of Science (PhD)
Московский государственный университет имени М.В.Ломоносова, Геологический факультет, Кафедра теоретических основ разработки месторождений нефти и газа, Москва, Россия
E-mail: yahwang23@163.com

Annotation. *Understanding the thermo-mechanical behavior of shale under high-temperature and pressure conditions is critical for geothermal energy and deep oil and gas resource extraction. This study investigates the triaxial compressive mechanical response of shale under real-time high-temperature conditions (RT-350°C) and confining pressures (0-40MPa) using a self-developed high-temperature triaxial loading system. The results show that the peak stress decreases with rising temperature, accompanied by a transition from brittle to ductile failure. Conversely, increasing confining pressure enhances peak stress and partially mitigates thermal-induced strength degradation by suppressing crack propagation through lateral constraint. The coupling effect indicates that temperature governs strength reduction, while confining pressure controls deformation. These findings provide insights into the thermo-mechanical evolution of shale and offer a theoretical basis for the effective exploitation of deep-earth resources and the efficient utilization of deep-earth space.*

Keywords: *thermo-mechanical coupling, triaxial compression experimental system, shale.*

The exploitation of ultra-deep oil and gas resources encounters dual challenges of high temperature and high geostress, necessitating fundamental insights into rock mechanical behavior and failure mechanisms under coupled thermo-mechanical conditions[1, 2]. Most of the existing related experiments require the rocks to be heat-treated in advance or to be at real-time high temperature but without confining pressure. In addition, most temperature-related experiments have focused on granite and sandstone[3], with fewer studies on shales. This investigation employs a self-developed real-time high-temperature triaxial loading system to simulate ultra-deep reservoir environments, systematically characterizing the strength evolution, failure mode, and damage mechanism of shale. Experimental results demonstrate significant synergistic and competitive interactions between thermal and confining effects. The temperature increase from RT to 350°C resulted in a 81-86% drop in peak stress from 50-105 MPa to 16-19 Mpa, accompanied by a brittle-to-ductile failure mode transition. Confining pressure enhances peak strength and delays failure strain through lateral constraint mechanisms that suppress crack propagation, though insufficient to fully counteract thermal degradation. These findings suggest that temperature governs strength deterioration through thermal softening mechanisms, while confining pressure provides partial compensation through enhanced frictional resistance and crack closure effects.

References

1) Zhou Z, Zhang F, Fu H, Xiu N, Guan B, Cai B. A thermal–mechanical coupled DEM model for deep shale reservoir: the effects of temperature and anisotropy. ROCK MECH ROCK ENG. 2024;57:3707-26.
2) Zheng Z, Tang H, Zhang Q, Pan P, Zhang X, Mei G, et al. True triaxial test and PFC3D-GBM simulation study on mechanical properties and fracture evolution mechanisms of rock under high stresses. COMPUT GEOTECH. 2023;154.