International Core Journal of Engineering Volume 8 Issue 2, 2022
ISSN: 2414-1895 DOI: 10.6919/ICJE.202202_8(2).0067

Analysis of Creep Failure Characteristics of Silurian Longmaxi Shale in Sichuan Basin

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Abstract

In recent years, the exploitation of shale gas in southwestern Sichuan, China, has increased significantly. But with the deepening of strata, the geological conditions become complex, and the mechanical properties of shale change with the increase of ground stress and geothermal. Creep is one of the important mechanical properties of rock, which affects the long-term stability of rock engineering. Therefore, this paper carried out triaxial creep test with the rock mechanics test system, and obtained the rock mechanics characteristics of shale under different conditions. The research results are of great significance for elucidating the creep deformation and failure characteristics of shale under high temperature and high ground stress conditions, and can provide important basic information for the exploration and development of shale gas reservoirs.

Keywords

Triaxial Creep; Shale Rock; High Temperature; High Ground Stress.

1. Introduction

Creep of rock refers to the phenomenon that rock deformation increases with time under constant stress and temperature [1-2]. Creep is one of the important mechanical characteristics of rock. The shale gas mining process often encounter problems such as wellbore instability. Therefore, studying the failure characteristics of shale is conducive to analyzing its deformation characteristics and providing constructive guidance for engineering [3-4].

In the past, many experiments have studied the mechanical properties of materials at different temperatures or confining pressures [5-8]. The results show that the compressive failure strength of the material decreases significantly with the increase of temperature and the decrease of confining pressure. In addition, on the mechanical properties and creep behavior of shale, some scholars analyzed and studied the material properties of shale through laboratory tests and outdoor practical engineering [9-10].

In this paper, a triaxial creep test of shale was carried out by using the rock mechanics test system, and the mechanical and acoustic characteristics of shale under different temperatures and confining pressures were obtained.

2. Research Method

2.1 Experiment Equipment

The experiment equipment used in this test is MTS815 Flex Test GT rock mechanics test system and PAC PCI-2 12 channel acoustic emission tester, as shown in Fig 1. The system is mainly composed of confining pressure loading system, osmotic loading system, axial loading system and general control system. The major technical parameters of MTS 815 are listed in Table 1.

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Fig. 1 MTS815 rock test system

Table 1. Major tenical parameters of MTS815

Axial load (kN)	Confining pressure (MPa)	Operating temperature (°C)	Axial extensometer (mm)	circumferential extensometer (mm)	Measured accuracy
0~4600	0~140	20~200	-5~5	-2.5~8	0.5%

2.2 Test Scheme

(a) (b)

Fig. 2 Shale specimens (a) complete specimen before test, (b) destructive specimen after test.

Table 2. Triaxial test conditions and loading stress

Specimen number	Z1	Z2	Z3	Z4	Z5
Confining pressure(MPa)	10	20	30	10	10
Temperature(°C)	25	25	25	60	90

In this paper, shale outcrops in southern Sichuan are selected as specimens. The size is a standard cylindrical sample of Φ50mm × 100mm processed by the national standard. The shale specimens before and after triaxial compression test are shown in Fig. 2. Five groups of triaxial compression tests were carried out. The confining pressure and temperature were controlled as different variables, and the confining pressure was set to 10, 20 and 30 MPa respectively. Otherwise, temperature was set to 25 °C, 60 °C, 90 °C respectively, the specific test plan is shown in table 2.

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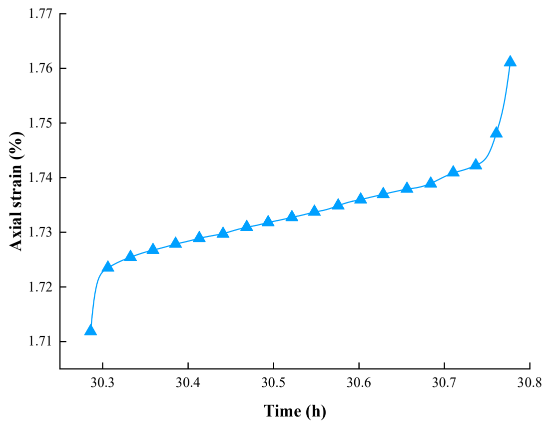
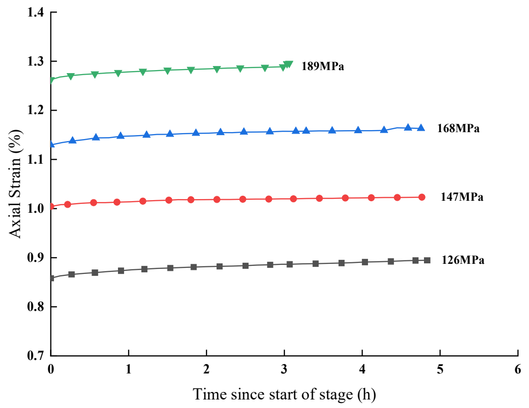
3. Results and Discussion

3.1 Creep Characteristic

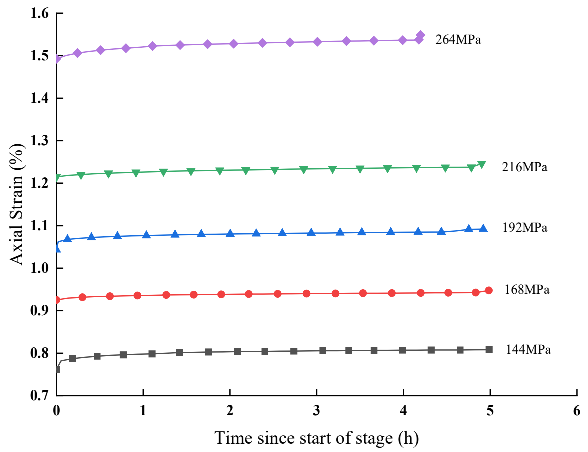
Through this test, the creep curves of shale at all levels were obtained. The results show that the strain of shale under various loads is composed of three parts: initial strain, deceleration creep strain and steady creep strain with stable creep rate, as shown in Fig 3 (a). And under the condition of constant confining pressure, the instantaneous strain and creep strain increase with the increase of axial pressure.



(a)



(b)



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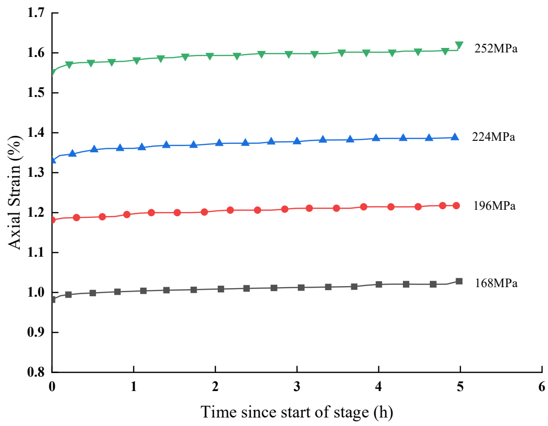

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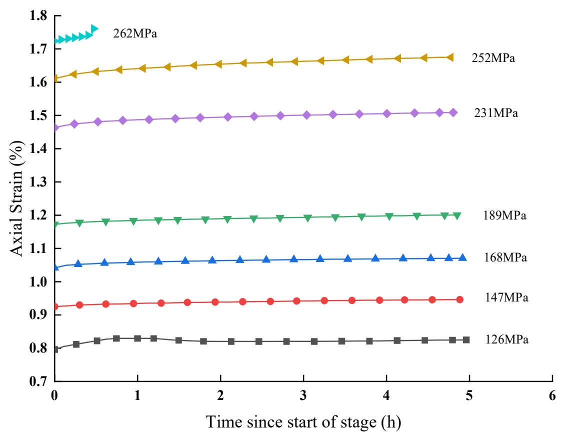
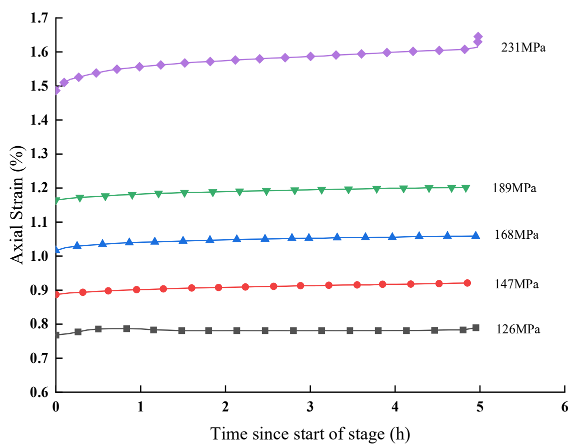


(e)



(f)

Fig. 3 Strain-time test curveAcoustic emission characteristics

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Acoustic emission monitoring was also carried out during the test. The results showed that the acoustic emission hits maintained at a very low level during the whole loading process, but the acoustic emission activity was more active at the initial and final stages of the test, and a mutation occurred at the end of the test. At this time, the crack propagation stage entered, and the cracks in the rock increased slightly, resulting in a large number of acoustic emission signals, as shown in Fig. 4.

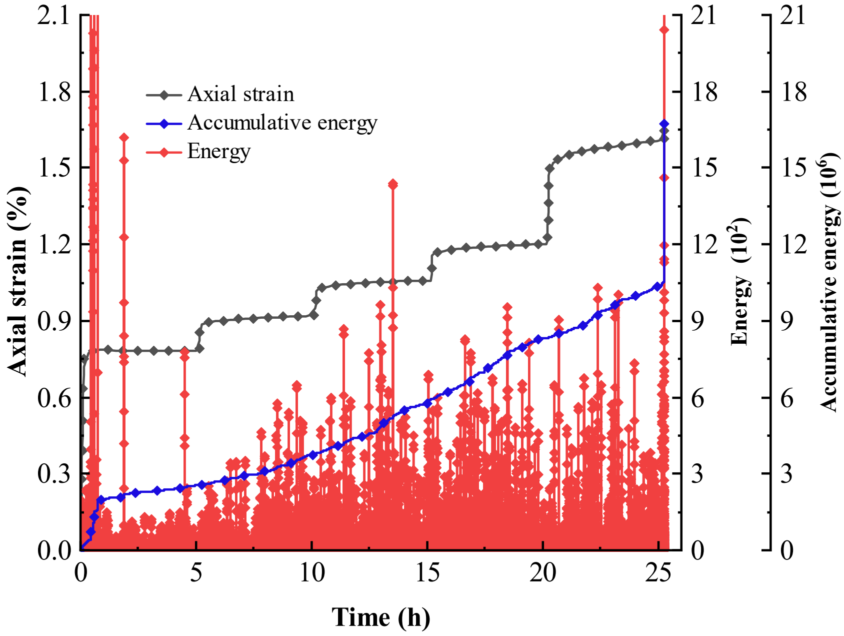

Fig. 4 Acoustic emission hits - time curve

3.2 Analysis of Different Temperature and Confining Pressure

Combined with the strain-time test curve (Fig. 3) and its acoustic emission hits - time curve (Fig. 4) under different conditions, the analysis is as follows:

(1) In the case of different confining pressures and the same axial compression, the strain first decreases and then increases with the increase of confining pressure. Taking the test results of three groups of samples under confining pressure of 10 MPa, 20 MPa and 30 MPa as an example, when the axial compression is 168 MPa, the strain is 0.286 %, 0.216 % and 0.255 % respectively. The maximum loading values gradually increased with the increase of confining pressure, which were 189.1 MPa, 268.0 MPa and 305.1 MPa, respectively. The acoustic emission hits of the three samples remained at a very low level during the whole loading process, and a mutation occurred only at the end of the test, resulting in a large number of acoustic emission signals. The cumulative hits of Z1, Z2 and Z3 were 981400, 93920 and 36059 times, respectively. Therefore, the cumulative hits decreased with the increase of confining pressure.

(2) Under a certain confining pressure, due to the temperature effect, water and gas are volatilized from shale, as well as the thermal expansion of minerals and crystals in shale. Therefore, the strain of Z4 and Z5 samples appears an inverse value at the heating stage, and increases with the increase of temperature. The maximum values of the inverse strain of Z4 and Z5 samples are 0.197 % and 0.855 %. In general, the total strain increases with the increase of temperature. Taking the test results of three groups of samples Z1, Z4 and Z5 as an example, the maximum strain is 0.335 % at 25 °C. When the temperature is 60 °C, the maximum strain is 1.701 %; when the temperature is 90 °C, the maximum strain is 4.042 %. The cumulative hits of acoustic emission on the body increases with the increase of temperature. Taking the test results of Z4, Z4 and Z5 as examples, when the temperature is 25 °C, the cumulative hits is 981400 times; when the temperature is 60 °C, the cumulative hits is 1382000 times; when the temperature is 90 °C, the cumulative hits is 4353000 times.

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4. Conclusion

Combined with the test creep curve and acoustic emission monitoring comprehensive analysis. Temperature and confining pressure are closely related to shale strength properties. Specifically, under the conditions of higher temperature and lower confining pressure, with the increase of axial pressure, the strength of shale shows a gradual downward trend. The research results are of great significance to guide practical engineering.

References

[1] CaiMF, He M C, Liu D Y. Rock Mechanics and Engineering. 2nd Ed. Beijing: Science Press, 2019.

[2] Sun J. Rheological Behavior of Geomaterials and its Engineering Applications. Beijing: China Architecture and Building Press, 1999.

[3] XIE He-ping, GAO Feng, JU Yang, et al. Novel idea and disruptive technologies for the exploration and research of deep earth[J]. Advanced Engineering Sciences, 2017, 49(1): 1–8.

[4] LI Xi-bing, ZHOU Jian, WANG Shao-feng, et al. Review and practice of deep mining for solid mineral resources [J]. The Chinese Journal of Nonferrous Metals, 2017, 27(6): 1236– 1262.

[5] Closmann P J, Bradley W B. The Effect of Temperature on Tensile and Compressive Strengths and Young's Modulus of Oil Shale. Society of Petroleum Engineers Journal 1979; 19(5):301-312.

[6] Zeuch D H. The mechanical behavior of Anvil points oil shale at elevated temperatures and confining pressures. Canadian Geotechnical Journal 2011; 20(2):344-352.

[7] Meng Lubo, Li Tianbin, Xu Jin, et al. Experimental study on influence of confining pressure on mechanical properties of shale under high temperature. Journal of China Coal Society; 2012 (11): 1829-1833.

[8] Masri M, Sibai M, Shao J F, et al. Experimental investigation of the effect of temperature on the mechanical behavior of Tournemire shale. International Journal of Rock Mechanics & Mining Sciences 2014; 70(Complete):185-191.

[9] Gasc-Barbier M, Chanchole S, Berest P. Creep behavior of Bure clayey rock. Applied Clay Science 2004; 26(1/4):449-458.

[10] Chang C, MD Zoback. Viscous creep in room-dried unconsolidated Gulf of Mexico shale (I): Experimental results. Journal of Petroleum Science and Engineering 2009; 69(3):239-246.