Academic Journal of Engineering and Technology Science
ISSN 2616-5767 Vol.5, Issue 1: 28-33, DOI: 10.25236/AJETS.2022.050106

Influence of High Pressure Fluid on the Competence of Porous Clastic Rock

Zhe Liu[a*], Jiajing Li[b], Ming Hu[c], Lei Pang[d], Fengying Guo[e]

School of Petroleum Engineering, Guangdong University of Petrochemical Technology, Maoming 525000, Guangdong, China
[a]liuzhe@gdupt.edu.cn, [b]lijiajing@gdupt.edu.cn, [c]suphuming@126.com, [d]panglei08@qq.com, [e]1132844763@qq.com
**Corresponding author*

Abstract: *In porous clastic rocks, the uneven distribution of high-pressure fluid will cause changes in water saturation and frequent changes in wavelength. The purpose of this article is to study the effect of high-pressure fluid on the competence of porous clastic rocks. First, according to the dynamic high pressure technology of the two-stage light gas gun and the compressed gas target technology, the principle of dynamic high pressure loading is introduced and the rock competence in the rheological process is analyzed. The traditional Gassmann equation is adjusted to match the temperature to verify the fluid mechanism model of the porous medium. The impact of high-pressure jet on the rock surface of porous clastic rock and the influence factors of high-pressure pulse jet on rock are discussed. The experimental results show that the rock damage effect is better when the distance between adjacent pulsed jets is 9mm.*

Keywords: *High-pressure Fluid, Porous Clastic, Clastic Rock, Rock Competence*

1. Introduction

As the basis of fluid replacement, Gassmann's standard medium method analyzes the change of porosity by calculating the total medium and density velocity [1-2]. Therefore, it is very important to study several different layers including water rocks under different temperature conditions [3]. In the process of tectonic deformation, the rock will record some information of strain, which can reflect the deformation mechanism of various tectonic processes to a certain extent [4]. Under the same geological conditions, due to the differences in composition and structure of different types of rocks, they also show certain differences in the deformation process. This is the difference in rock competence. The competence of rocks is generally described by strength and weakness, brittleness and toughness, and hardness and softness [5].

The action of high-pressure fluid has become a hot research topic [6]. Yehya M focuses on introducing a new experimental device for studying fluid flow under high pressure gradients in low-permeability porous media through neutron imaging. A titanium Hassler battery that optimizes neutron transparency while allowing high pressure limitation (up to 50 MPa) and injection is designed for this purpose and is shown here. Since some preliminary results have been obtained on the D50 beamline of the Lloyd-Langevin Institute (Grenoble) using a new neutron imaging device called NeXT, this contribution focuses on the development of the proposed method [7]. After the Runstedtier A computational fluid dynamics (CFD) model has been validated, it can be used to help design a full-scale reactor. Model validation requires comparing model predictions with laboratory-scale or pilot-scale measurements. However, the experimental measurements of high-pressure pilot-scale gasifiers usually only include wall temperature and outlet gas temperature and composition. When the gasifier is operating well, this information is of limited use for model verification, and only provides information about operating temperature, heat loss, and balance. Gas composition. These do not provide a strong verification of the CFD model. Its main purpose is to predict the size and shape of the flame, and its ability to effectively convert solid fuels into gases in a small volume [8]. It is of practical significance to study the influence of high-pressure fluid on the competence of porous clastic rocks.

In this paper, a nonlinear seepage experiment under high confining pressure is carried out for fractured rock mass. The research results can be used as the theoretical basis of rock hydraulics. The fluid distribution will not affect the shear modulus, that is, the uniform or uneven distribution of the fluid will not change the shear wave. We found that when the porous clastic rock is saturated with three fluids, the shear wave response is no longer a purely linear relationship with the total water saturation, but an inflection point appears. This is because the density of the three-phase fluid-saturated rock has occurred. Change, which leads to a slight change in the speed of the transverse wave.

2. Study on the Influence of High-pressure Fluid on the Competence of Porous Clastic Rock

2.1 The Principle of Dynamic High Pressure Loading

In the laboratory, static high pressure and dynamic high pressure technology can be used to generate high temperature and high pressure conditions [9]. The highest pressure reached by the static high pressure technology is about 500GPa, combined with laser heating technology can also raise the temperature to thousands of degrees. However, DAC loading technology can only achieve ultra-high pressure in micron-level samples, which is not conducive to the detection of material properties [10]. On the contrary, dynamic high-pressure technology based on shock waves can achieve high-temperature and high-pressure loading of millimeter-scale samples [11].

(1) Two-stage light gas gun dynamic high pressure technology

The secondary light gas gun is a commonly used tool in high-pressure physics experiments. It has the characteristics of mature technology, large sample size, and rich detection methods. Its working principle is as follows. "After igniting the gunpowder, when the pressure in the gunpowder chamber exceeds a certain leap value, the large diaphragm ruptures. The gas inside the gunpowder chamber suddenly pushes the piston to do work, compressing the gas (usually hydrogen) pre-filled in the pump tube to make its pressure equal to The temperature continues to rise [12]. When the internal pressure of the pump tube exceeds the pressure that the small diaphragm can withstand, the small diaphragm ruptures instantly. The high-pressure gas enters the launch tube and the projectile moves at high speed, and finally hits the target to generate a shock wave. The time to hit the target is usually less than one microsecond, but the pressure can reach hundreds of GPa, and the temperature can reach several thousand K. During this time, it is possible to detect and record the sample in the target under ultra-high pressure under the action of the shock wave. The physical characteristics. The whole process is very short, requiring a complete set of equipment to have a very high response rate.

Under normal conditions, the density of hydrogen is very low. In order to obtain a large-scale high-temperature and high-pressure fluid state, two techniques can be adopted. First, increase the pressure of the initial gaseous sample; second, use the sandwich sample design and compress the sample with multiple impact techniques.

(2) Compressed gas target technology

A self-developed gas pressurizing device is used to pre-press the gaseous samples. First, a certain amount of gaseous sample is injected into the high-pressure gas cylinder, and then pressurized by the high-pressure pump to the required compression state, and then the compressed gas is injected into the sample target through the valve, and the air pressure is detected by the meter. When the pressure in the sample chamber reaches a predetermined value, close the valve to maintain the pressure, and wait for the impact test.

2.2 Rock Competence in the Process of Rheology

The application of rheometer has a certain significance for studying the effect of fluid in the rheological process, and it is helpful to explore whether the brittle-ductile transition mechanism is gradual or abrupt. According to the different research objects, the structural rheometer can be divided into: capable layer fold rheometer, residual patch wing tail style rheometer, true strain difference refractometer and matrix block structure rheometer. We choose different rheometers for analysis under different actual conditions. The finite strain is usually used to express the magnitude of the strain value after the rock is deformed. In the same deformation environment of two different types of adjacent rocks, the rock with small strain has high competence and high viscosity; the rock with large strain has low competence and low viscosity. For example: different lithological layers with the same thickness are squeezed horizontally in the same matrix to produce folds. Compared with the surrounding matrix layer, the folds with a larger initial wavelength have higher capability and higher viscosity; those with a smaller initial wavelength are capable Lower and lower viscosity. In the wild, a series of sharp round folds are formed on some highly capable layers, that is, folded window ridge structures, with their tips pointing to highly capable rock formations. Rotating phenocrysts in the rock have higher competence (viscosity) than the base competence (viscosity). The σ-shaped fragmented plaque structure with residual plaques and wing tail patterns indicates that the matrix has Newtonian properties.

3. Investigation and Research on the Influence of High-pressure Fluid on the Competence of Porous Clastic Rock

3.1 High-pressure Fluid Test System

This article uses the Triaxial Cell three-axis THM coupling test system produced by the French TopIndustrie company. And permeation test under triaxial stress state, as well as a variety of combinations of temperature, fluid, mechanics, chemistry and other multi-field coupling tests. The whole system is composed of loading system, computer control system, triaxial pressure chamber, data acquisition device, infiltration device and other parts. Among them, the automatic triaxial seepage rheology servo instrument for rock (TriaxialCellV3) has the functions of uniaxial compression, triaxial compression, permeability test, rheological test and so on. The loading methods of the test equipment include stress control, strain control and flow control. The confining pressure and the axial bias are controlled by two hydraulic pumps with an accuracy of 0.1MPa. Axial strain is measured by LVDT (that is, linear variable differential transformer), and hoop strain is measured by hoop strain gauges attached with strain gauges. The high-performance data acquisition board device can record the load, stress, displacement and strain during the test in real time, and can simultaneously draw the relationship curve of load displacement, stress and strain.

3.2 Sample Preparation

The samples used in the test were taken from the quarry in the Beishan preselected area of the high-level radioactive waste repository. The measured confining pressure was 10-15Mpa on site, and the porous clastic rock was selected as the research object. According to the idea of experimental design, the process of preparing granite artificial porous fragments is as follows:

(1) After the rock sample is retrieved, the granite needs to be cut first to obtain a regular cuboid rock block with a size of 200×120×120mm;

(2) In order to avoid the size effect in the process of generating cracks, that is, when the size of the split sample is smaller, the crack surface formed is smoother. In order to make the research object closer to the actual crack, the experiment first uses the Brazilian split method to compare The cuboid rock block is split to generate an artificial fracture parallel to the long axis of the granite cuboid block;

(3) After obtaining the crack that penetrates the entire block, re-splice the sample on the outer surface of the crack with silica gel along the direction of the crack;

(4) The standard rock core is drilled by the water drilling method. In order to ensure that the upper and lower sides of the core are flat, both ends need to be polished and the prepared standard cylindrical core samples are cut.

3.3 Fluid Mechanism Model of Porous Media

Dry rock is defined as pore compression, which only affects changes in bone volume without causing changes in pore pressure, and is not compressed rock. There is a strong relationship between very elastic modulus and porosity:

$$\frac{1}{K_{dry}}=\frac{1}{K_{ma}}+\frac{\phi}{K\phi} \tag{1}$$

Among them, ϕ represents porosity, k_{ma} represents the elastic modulus of the matrix mineral, and $K\phi$ represents the hardness of dry pores. The similar relationship between the bulk elastic modulus and the filling water of the porous medium can be obtained:

$$\frac{1}{K_{sat}}=\frac{1}{K_{ma}}+\frac{\phi}{K\phi} \tag{2}$$

K_{sat} represents the bulk elastic modulus of the pore fluid. When the properties of the pore fluid in the medium change, the Gassmann equation reflects the changing characteristics of the elastic modulus of the fluid medium.

4. Investigation and Analysis of the Influence of High-pressure Fluid on the Competence of Porous Clastic Rocks

4.1 Changes in Surface Morphology of Porous Clastic Rock by High-pressure Jet Impact

Analyze the seepage characteristics under the change of the fracture surface morphology, as shown in Figure 1. The fracture surface is deformed under the action of confining pressure, the pores are gradually compressed, and then the contact area of the upper and lower fracture surfaces begins to increase slowly, and at the same time, some ridges with higher undulations on the fracture surface are gradually flattened. At this time, the lower bulge gradually dominates the process of seepage influence. In addition, the increase in the contact area of the upper and lower fissures affects the water flow path, resulting in complex and tortuous water flow channels in the gaps. The flattening will weaken the non-linear effect of the flow pattern. The entire loading process can be divided into two stages: the initial stage of the loading and the middle and later stages of the loading. In the initial stage of loading, the bulge on the surface of the fracture controls the nonlinearity of the water flow. As the higher bulge is slowly crushed and flattened, the nonlinear effect of the water flow is gradually weakened. In the middle and late stages of loading, with the further increase of the confining pressure σ_n, the contact area of the upper and lower fissures continues to expand, making the seepage path in the fissure gap more tortuous. Intensified the non-linearity of the flow pattern of the water in the fissure.

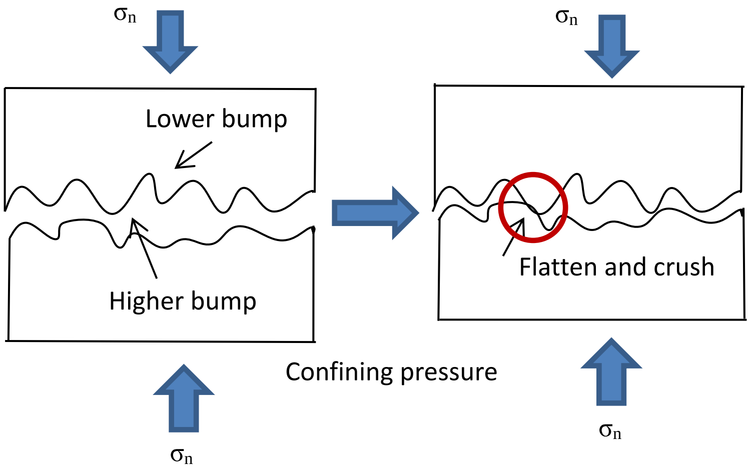

Figure 1: Schematic diagram of variation of crack surface undulation under confining pressure

4.2 Analysis of Factors Affecting Rock Impact by High-pressure Pulse Jet

Adjacent pulse jet separation is used to replace the pulse frequency, and the impact time is 25μs. When the distance l_2 between adjacent pulse jets is 4mm, the damage zone is the smallest, 4.1mm, and the length of the mature cone crack is the shortest. As the distance increases, the damage zone increases, and the mature cone crack inside the rock lengthens. When the distance is small, the thin water film formed on the free surface of the rock by the first pulse jet fails to disappear, which produces a "water buffer effect" for the latter pulse jet, which reduces the damage to the free surface of the rock by the latter pulse jet. When the distance between adjacent pulse jets is 9mm, the length of mature cone cracks does not increase significantly, and the damage zone does not increase significantly.

The maximum length of mature cone cracks in the rock under different pulse jet spacings is shown in Figure 2. The maximum length of cone cracks increases exponentially with the increase between adjacent pulse jets, indicating that its expansion has certain limitations. When the distance exceeds a certain value, the length of the cone crack no longer increases, and the size of the damage zone increases slowly. Therefore, in order to achieve beneficial effects, it is necessary to select the jet frequency reasonably. When the distance l_2 between adjacent pulse jets in this paper is 9mm, the rock damage effect is better.

Table 1: The length of cone cracks in the rock under different jet column spacing

l_2	Length	$y=4.04+e^{-0.21x}$
4	2.3	2.1
5	2.6	2.5
6	2.8	3.3
7	4	3.8
8	4.3	4.2
9	4.5	4.6

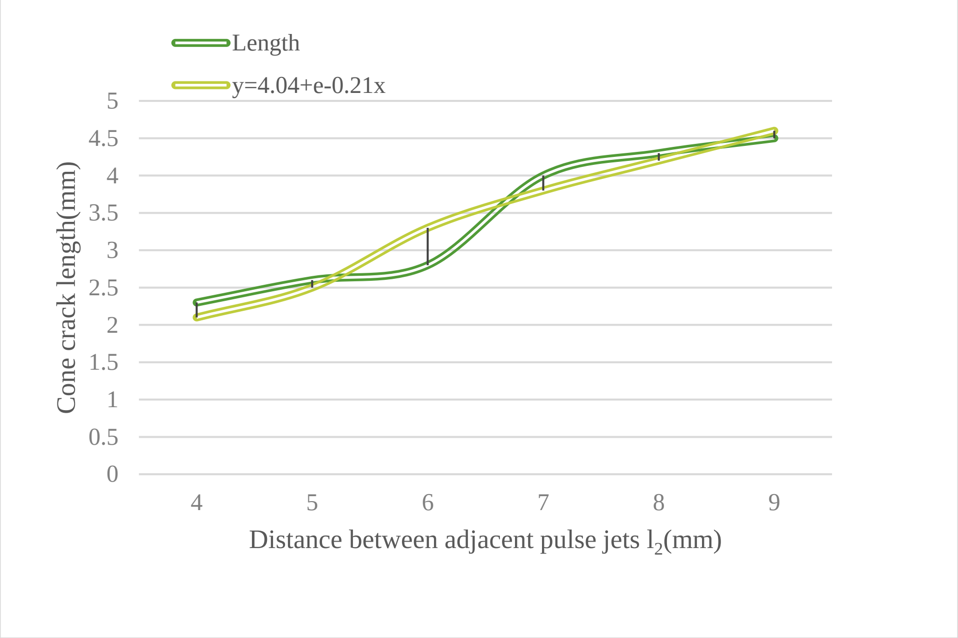

Figure 2: The length of cone cracks in the rock under different jet column spacing

5. Conclusions

The rheological process of rock is complicated, and the rheological action is very obvious. Various natural rheological signs of rock are formed in the rock, including strain refraction of veins, lattice structure and small folds. Based on the deformation characteristics of the rock field, this paper can make a comparison of the competence of different types of rocks in the area, analyze and compare the differential rheological behaviors of different types of rocks, and discuss the kinematic characteristics, formation age, tectonic traces and characteristics of the tectonic deformation zone. Combining characteristics reveals the relationship between rock composition and structure and its rheological behavior, perfects the comparison of the competence of different types of rocks in the area, and finds out the factors that affect the difference in rock competence. Analyzing the anatexis process of early magma, revealing the main controlling factors in the rheological process of rocks and their mutual restraints.

Acknowledgements

This work was supported by The National Natural Science Foundation of China (41602154) and Projects of Talents Recruitment of GDUPT (2018rc01)

References

[1] Traxinger C, Pfitzner M . Effect of nonideal fluid behavior on the jet mixing process under high-pressure and supersonic flow conditions[J]. Journal of Supercritical Fluids The, 2021,

172(6):105195.

[2] Kagi H , Kubo T , Shinozaki A , et al. Reaction between Forsterite and Nitrogen Fluid at High Pressure and High Temperature[J]. Geochemistry International, 2019, 57(9):956-963.

[3] Ji Z . Research on thermal-fluid-structure coupling of valve plate pair in an axial piston pump with high pressure and high speed[J]. Industrial Lubrication and Tribology, 2018, 70(6):1137-1144.

[4] Hamza M F , Soleimani H , Merican Z , et al. Nano-fluid viscosity screening and study of in situ foam pressure buildup at high-temperature high-pressure conditions[J]. Journal of Petroleum Exploration and Production Technology, 2020, 10(3):1115-1126.

[5] Halama R , Konrad-Schmolke M , JCMD Hoog. Boron isotope record of peak metamorphic ultrahigh-pressure and retrograde fluid–rock interaction in white mica (Lago di Cignana, Western Alps)[J]. Contributions to Mineralogy and Petrology, 2020, 175(3):1-19.

[6] Daridon J L , Lin C W , Carrier H , et al. Combined Investigations of Fluid Phase Equilibria and Fluid–Solid Phase Equilibria in Complex CO2–Crude Oil Systems under High Pressure[J]. Journal of Chemical And Engineering Data, 2020, 65(7):3357-3372.

[7] Yehya M , E Andò, Dufour F , et al. Fluid-flow measurements in low permeability media with high pressure gradients using neutron imaging: Application to concrete[J]. Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment, 2018, 890(MAY11):35-42.

[8] Runstedtier A , Yandon R , Duchesne M , et al. Conversion of Petroleum Coke in a High-Pressure Entrained-Flow Gasifier: Comparison of Computational Fluid Dynamics Model and Experiment[J]. Energy & Fuels, 2017, 31(5):5561-5570.

[9] Paknejad A , Mohammadkhani R , Zarei H . Experimental High-Temperature, High-Pressure Density Measurement and Perturbed-Chain Statistical Associating Fluid Theory Modeling of Dimethyl Sulfoxide, Isoamyl Acetate, and Benzyl Alcohol[J]. Journal of Chemical And Engineering Data, 2019, 64(12):5174-5184.

[10] Rodriguez C , Rokni H B , Koukouvinis P , et al. Complex multicomponent real-fluid thermodynamic model for high- pressure Diesel fuel injection[J]. Fuel, 2019, 257(Dec.1):115888.1-115888.28.

[11] Galvis V , Berrospi R D , Tello A , et al. Interface Fluid Syndrome (IFS) following Toxic Anterior Segment Syndrome (TASS): not related to high intraocular pressure but to endothelial failure[J]. Saudi Journal of Ophthalmology, 2019, 33(1):88-93.

[12] Basfar S , Ahmed A , Elkatatny S . Stability Enhancing of Water-Based Drilling Fluid at High Pressure High Temperature[J]. Arabian Journal for Science and Engineering, 2021, 46(7):6895-6901.