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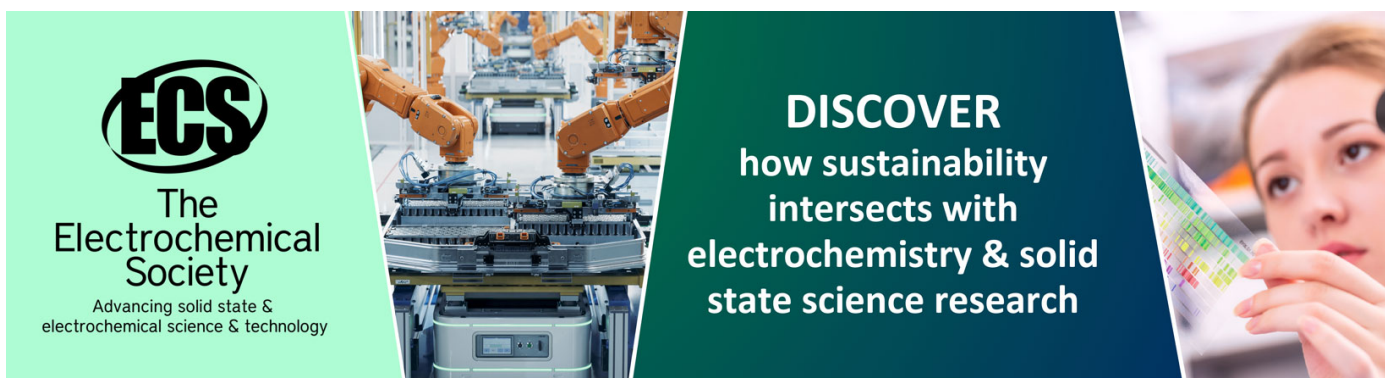
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A Test Device System for Cracking Mud Shale under Hydraulic Fracturing

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Abstract. The exploitation of shale gas has always been a major problem, and the solution to this problem must start with the study of its nature. A kind of simulation device and monitoring method of mud shale cracking was designed and assembled by ourselves. First of all, made with two layers of the general principle and four layers of 60 ° prefabricated crack two groups of similar material sample of the shale, then in turn for each block of multistage hydraulic fracturing test, and the use of strain gauge for strain monitoring. Results show that under the condition of no native prefabricated crack, hydraulic direction tend to toward weak bedding plane direction of crack extension until she reached the weak bedding surface, and then the main cracks along the weak bedding surface directly, at the same time there are prefabricated crack in native and weak stratification plane, in stage and the area between the prefabricated crack priority area map cracking formation, the results for the exploitation of shale gas has important guiding significance.

1. Introduction

Due to the development of bedding and complex geological conditions of mud shale itself, its reservoir is characterized by low porosity, low permeability and deep burial. In the process of exploiting shale gas with hydraulic fracturing technology, the borehole wall becomes unstable, the mining amount is small and the mining cost remains high. Since multistage hydraulic fracturing after internal micro crack extension of the shale evolution mechanism of the real physical process has been the lack of relevant research, so that the hydraulic fracturing technique in the process of shale gas and theory cannot be adapted to the actual project, severely restricted the development of shale gas efficiency, for shale gas exploration has always been a major problem in China.

At present, domestic and foreign scholars mainly use laboratory test and numerical simulation technology to study the hydraulic fracturing of shale. Jian Zhou [1, 2] et al. discussed the macro and micro influencing factors of the hydrofracture trend after the interference of natural fractures and hydrofractures, and studied the fracture opening and shear failure mechanism of natural fractures. Hao Jian [3] et al. made using of the combination of indoor triaxial loading device and CT machine scanner, injected water on the sample at the same time, simulated the propagation of internal crack in the rock with similar materials, and analyzed the law of micro-crack damage and development and evolution in



the rock from the perspective of microstructure. Xu Zhang [4] et al. conducted real-time monitoring of the process of shale water pressure cracking by using acoustic emission monitoring system in the room, established three-dimensional visualization fracture distribution map, and analyzed the tendency of hydrofractures developing along natural fractures. Yingtong Guo, Shuai Heng et al. [5, 6] used Disp acoustic emission and CT scanning to locate the interior space of mud shale, monitored the crack initiation location of hydraulic fracturing, and used tracer traces to track the growth and extension of micro-cracks, and described the development and evolution rules of micro-cracks. Shicheng Zhang [7] et al. carried out a simulation test of hydraulic fracturing fracture expansion on shale outcropping by using the large-size true triaxial test system, and observed the fracture morphology inside the core after pressure with high-energy CT scanning, and studied the influence of various factors on fracturing fracture expansion law of shale horizontal Wells. Zhi Li, Shicheng Zhang [8-10] et al. used CT machine and high-energy triaxial test to explore the fracture expansion mechanism of shale fracturing.

The above research results mainly focus on the hydraulic fracturing of rocks. In the fracturing analysis of mud shale, the relationship between the strain change of mud shale and the change of shale crack is seldom considered, and there are few studies on the influence of shale shale bedding characteristics and primary crack characteristics on the fracturing crack of mud shale. Based on the self-developed multi-stage hydraulic fracturing and monitoring device, this paper analyzes the influence of bedding characteristics and primary crack characteristics on the crack propagation and evolution of mud shale.

2. Hydraulic fracturing and monitoring test system

2.1. Research idea

In order to study the expansion form of mud shale fractures, the independently designed mud shale fracturing simulation device and monitoring system were used to conduct fracturing tests on the mud shale, and the trace of different color tracers on the cutting surface was tracked to characterize the extension law of hydraulic fractures. By changing the number of bedding and the location of prefabricated cracks, the influence of bedding and prefabricated cracks on the evolution of microcrack growth in shale was studied.

2.2. Test equipment

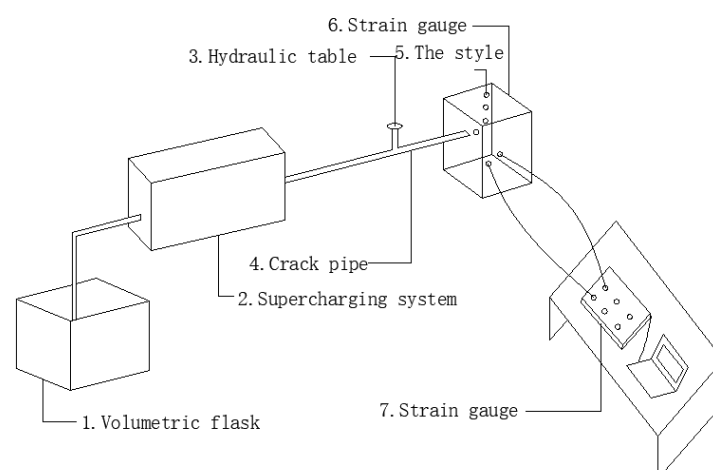


Figure 1. Multistage hydraulic fracturing system stereogram

Device composition: 1. volumetric flask; 2. Pressurization system; 3. Hydraulic pressure gauge; 4. Crack tube; 5. Sample; 6. Strain gauge; Strain gauge.

(1) The fracturing wellbore is made of high-strength steel tube, with a total length of 23cm. Each section is closely connected and sealed with adhesive. The wellbore was cracked. The physical picture of the fracturing wellbore is shown in figure 2.



Figure 2. Fracturing shaft



Figure 3. Split pipe and fracturing shaft combination

(2) The fracturing tube is put into the fracturing wellbore and the fracturing hole is in phase alignment. The physical drawing of the combined device is shown in figure 3.

(3) The rated pressure of the booster pump is 1.1mpa, the voltage of the power adapter is 12v, and the current is 12a; the range of the pressure gauge is 0-1.6mpa. The physical diagram of the booster pump is shown in figure 4.



Figure 4. Ressure pump

(4) When strain gauge is used for monitoring, the panorama main view of the mud shale fracturing simulator is shown in figure 5.



Figure 5. Test Panorama Front View

As shown in figure 1, it is the elevation diagram of the multi-stage hydraulic fracturing device. A fracturing tube and a fracturing sleeve were placed inside the mud shale sample, and a strain gauge was affixed to the surface of the prepared mud shale sample and connected to the strain gauge. The mud shale test block was put into the loading steel plate, and the nut was tightened to give the sample a certain confining pressure, so that the horizontal principal stress was slightly less than the vertical principal stress. Connect each joint of booster pump and fracturing pipe, start up the booster pump to start fracturing, and record consumption of fracturing fluid, fracturing time, change of pressure gauge reading and data of strain gauge. When the strain displayed on the strain gauge changes greatly, stop fracturing.

3. The test process

3.1. Sample preparation

In this test, C32.5 silicate cement, gypsum powder and natural river sand with particle size of 0.3mm~0.6mm were used as raw materials to physically synthesize mud shale test blocks, so as to simulate the crack growth law of layered mud shale fractured by water pressure. The layered material is composed of cement and soil, among which cement is C32.5 silicate cement, accounting for 6% of the total quality. Fine grained soil with a mass ratio of 94%. The strength of synthetic soil-cement is slightly lower than that of similar materials to replace weak bedding surface.

Weigh appropriate amount of cement, gypsum, river sand, water and soil, and apply mold release agent inside the mold. The similar materials are made of river sand, cement, gypsum powder, and water. According to the mass ratio of river sand: cement: gypsum powder: water = 6:1:0.36:0.36, pour them into a blender and mix well; then the cement soil with cement content of 6% was stirred and evenly poured into the mold for 1cm, and placed on the vibration table for compaction as the bedding of the sample; all sections of the wellbore shall be tightened, and a layer of high-strength adhesive shall be applied on the outer surface of the wellbore (except for the hole causing fracture), and the hole causing fracture shall be sealed with cotton balls. After 15min, the wellbore shall be placed in the middle of 30*30*30cm sample, and then the mixed materials shall be superimposed and poured into the mold to make a 30*30*30cm mud shale simulated sample. Block in room temperature 20 °C curing mold release in 2 days. Among them, the precast crack was replaced by the printing paper. The printing paper with a length of 8cm and a width of 8cm was placed in the direction of 60 degrees from the bedding surface above the bedding as the precast crack, and the pouring continued. The prepared samples are shown in FIG. 6 and FIG. 7.



Figure.6 Contains 2 layers of bedding sample



Figure.7 Sample with 60° precrack

3.2. Test steps

(1) Apply high-strength adhesive to the seal of the sample and the fracturing wellbore, and continue curing at room temperature for 7 days. Fill a graduated beaker with water and add red ink to 1000ml of clear water. Fix the shale sample, tighten the nut, and give the sample a certain confining pressure, so that the horizontal principal stress is slightly less than the vertical principal stress.

(2) Rotate the first fracturing tube 1 into the wellbore, align the fracturing tube 1 and the fracturing hole on the wellbore vertically, and connect all interfaces successively. At the beginning of the first stage of hydraulic fracturing, the strain curve of the strain gauge surface over time was used to record the number of pressure gauges and the amount of fracturing fluid used in the beaker. When the strain displayed on the strain gauge changes greatly, stop fracturing.

(3) Fill a graduated beaker with water and add blue ink to the clear water. Pull tube 1 out and screw the second root into the wellbore. Align tube 2 vertically with the hole on the wellbore and connect all interfaces in turn. At the beginning of the second stage of hydraulic fracturing, strain gauge was used to record the change curve of strain on the surface of test block with time, the change of reading of pressure gauge and the amount of fracturing fluid used in the beaker. When the strain displayed on the strain gauge changes greatly, stop fracturing.

(4) After crack initiation, observe the crack changes in the appearance of the sample. The sample was then cut along the casing section with a cutter to observe the development of red and blue tracers inside. The strain change data of simulated crack was analyzed synthetically.

3.3. Test results and analysis



Figure.8 Front view



Figure.9 Side view



Figure.10 Cutting plane (a)



Figure.11 Cutting plane (b)

As can be seen from FIG. 8-11, the compressive strength of the test block is 3-5mpa, and the tensile strength is 0.3-1mpa. When the pressure of the cracking fluid in the cracking tube reaches 1.1mpa, the sample does not immediately generate cracks; under the condition of constant pressure of 1.1mpa, after the crack initiation time lasted for 25s, cracks began to appear. At the same time, the crack initiation pressure began to gradually relieve until the crack penetrated to the outer surface of the test block, and the pressure dropped to the lowest level. The crack initiation lasted for 60s, and no new cracks were generated. At this time, the first crack, the test block transverse through the main crack. Due to the crack near the tube is weak structural plane, perpendicular to the direction of crack pipe on the front of the main crack and crack pipe show roughly 90 ° direction. The test block was cut at different angles with a cutter. At the side of the test block, the hydraulic direction began to deflect and extended towards the weak bedding plane until the weak bedding plane was reached. Then the main fracture was directly generated along the weak bedding plane. Due to the excessive crack pressure in the first crack, the hydraulic crack track of the second crack is basically along the main crack generated after the first crack.

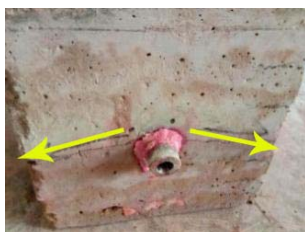


Figure.12 Front view after fracturing **Figure.13** Side view after fracturing **Figure.14** Cutting plane

As shown in FIG. 12-14, the compressive strength of the test block is 3-5mpa, and the tensile strength is 0.3-1mpa. When the pressure of the cracking fluid in the cracking tube reaches 1.1mpa, the sample does not immediately generate cracks. When the crack initiation time lasted for 25s under the condition of constant pressure 1.1mpa, the main crack as shown in FIG. 12 began to form. At the same

time, the crack initiation pressure began to gradually relieve until the crack penetrated to the outer surface of the test block, and the pressure dropped to the minimum. Since the first crack causes the main crack to expand in the direction perpendicular to the hole, the second crack does not produce new crack. Use cutting machine to cut block along the different angles, the prefabricated crack found near tracer, shows that the secondary to the trend of the development of the prefabricated crack to crack, can be predicted that if the block and prefabricated crack is large enough, then as you progress through the crack, hydraulic fracture will be prefabricated crack, and tend to track along the prefabricated crack development.

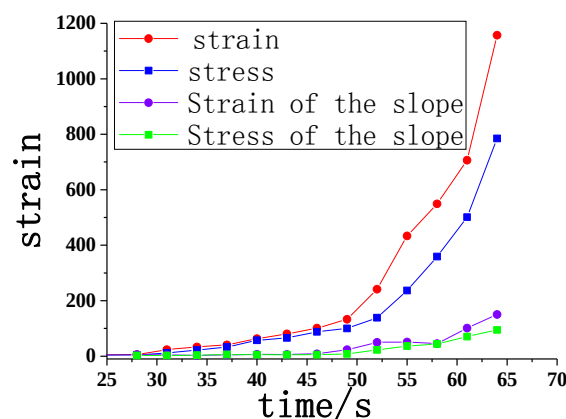


Figure.15 Time vs strain curve in the process of fracturing

As shown in figure 7, along the direction of the fracture location, 01 represents the lateral strain on the right side and 03 indicates the longitudinal strain above. As shown in figure 15, it is clear that in the first 25 seconds of hydraulic fracturing, there is little change in strain and no hydraulic crack; In the period from 25 seconds to 50 seconds, the strain increases steadily, and the microcracks begin to appear gradually. After 50 seconds, the transverse and longitudinal strain increases abruptly, and the micro-crack expands rapidly until the main crack of the test block is produced. At this time, the crack ends and the strain reaches the maximum value.

4. Conclusion

Through the multi-stage hydraulic fracturing test of shale simulated test block in laboratory, the following conclusions are drawn:

(1) In the absence of primary prefabricated cracks, the hydraulic crack direction tends to extend towards the weak lamellar surface until it reaches the weak lamellar surface, and then produces the main crack directly along the weak lamellar surface. In the case of prefabricated primary cracks and weak lamellar surfaces, large-area reticulated cracks are formed preferentially in the area between the prefabricated cracks and the prefabricated cracks.

(2) When the pressure of the first hydraulic fracturing is too high, it is easy to produce the penetrating main crack, and it is not easy to produce the secondary crack. The hydraulic main crack track of the second crack basically follows the main crack after the first crack, but does not produce the secondary fracture.

If a set of devices can be designed and the above two conditions can be taken into account, the conclusions of the study will be more accurate and persuasive if the shale samples with different temperatures and humidity can not be accurately applied under real formation conditions.

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