Journal of Intelligent Computing and Mathematics (ISSN Online: 2771-9952)
January 2024 Vol.3, No.1, pp. 94-97
DOI: https://doi.org/10.55571/jicm.2024.01029

Research on the Influence of Shale Reservoir Depth on Fracture Characteristics Based on Xsite

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Abstract. The exploration and development of shale reservoir is faced with both opportunities and challenges, especially the mechanism of influence of shale reservoir depth on hydraulic fracture characteristics is unclear. In this paper, by means of Xsite simulation, four stress levels are set to reflect the depth change from the side, and the influence of depth change on the hydraulic fracture characteristics of shale reservoir is studied. The results reveal a phenomenon: in the low stress environment, the fracture network can be effectively constructed, showing a more spacious space structure; In high-stress environments, the propagation direction of hydraulic fractures is precisely controlled, and these fractures can communicate more closely with the bedding surface. It is worth noting that in the low stress environment, the tensile fracture has a large area and forms a broad fracture network. In contrast, in high-stress environments, shear fractures dominate and their area increases significantly. In addition, the fracture volume is larger under low stress environment, while the total fracture area is more significant under high stress environment. This discovery has far-reaching significance for the formation of complex fracture networks in shale reservoirs, emphasizes the importance of making full use of shale multilayer characteristics, and provides rich and profound theoretical guidance for engineering practice.

Keywords. Shale; Depth, stress level, fracture characteristics, Xsite discrete lattice method

Citation: Qiu G.Z. and Li J. (2024). Research on the Influence of Shale Reservoir Depth on Fracture Characteristics Based on Xsite. Journal of Intelligent Computing and Mathematics, Vol.3, No.1, pp 94-97. https://doi.org/10.55571/jicm.2024.01029

Publication Date: February 2, 2024

1. Introduction

Shale hydraulic fracturing plays a crucial role in modern oil and gas extraction(Li et al., 2018b), however, there are some difficulties and challenges in the process of technology implementation. The in-situ stress of shale strata at different depths varies greatly, which affects the fracturing effect and the choice of fracturing strategy(Lin et al., 2017). The complexity of hydraulic fracture characteristics is determined by the rational characteristics of shale rock. Most studies on hydraulic fracturing of shale focus on the effects of stress difference, injection rate of fracturing fluid and viscosity. Huang(Huang et al., 2023) studied the influence of stress shadow effect on multi-fracture propagation. Chang(Chang et al., 2022)studied the effect of injection methods on the initiation and propagation of hydraulic fractures by laboratory experiments. Chang(Chang et al., 2024)studied the interaction between hydraulic fractures and natural fractures by means of laboratory experiments. Li(Li et al., 2018)studied the influence of rock brittleness on hydraulic fracturing by means of simulation.

However, the change of shale reservoir depth is often accompanied by the change of ground stress, so it has a great

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influence on the fracture characteristics. In this paper, based on Xsite discrete grid method, respectively, set up contrast test of σ_H: σ_h: σ_v: = 45:30:40MPa, σ_H: σ_h: σ_v: = all: 30MPa, σ_H: σ_h: σ_v: = rest: 20MPa, and σ_H: σ_h: σ_v: = 15:2:10MPa. The influence of shale reservoir depth on fracture characteristics was studied under the premise of constant stress difference.

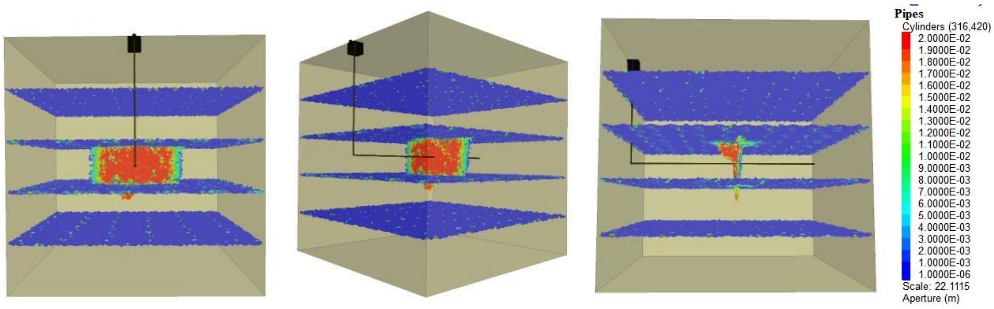
2. Model setup

According to the test requirements and relevant data, the parameters are set as follows:

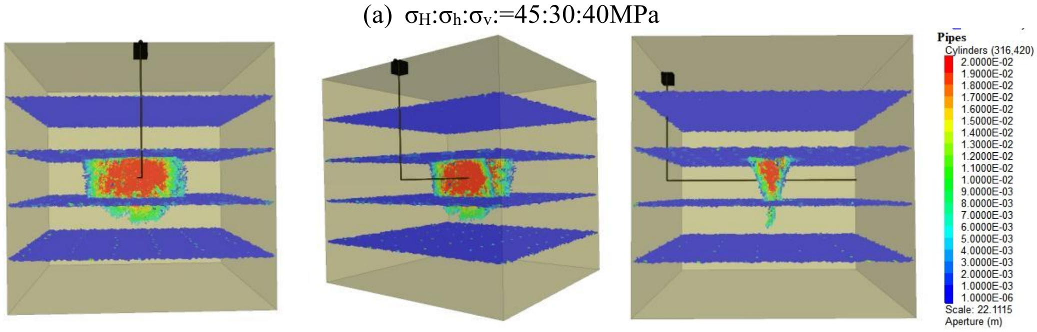
Tab. 1 Model parameters(Dezhi et al., 2023, Lv et al., 2022)

Name of parameter	Parameter value
Bedding quantity	4
Bedding friction Angle	30°
Cohesive force	15MPa
Tensile strength of bedding	8MPa
Vertical stress difference	10MPa
Horizontal stress difference	15MPa
Fracturing fluid viscosity	20mPa·s
Fracturing fluid rate	6m^3/min

3. Test results



(a) σ_H:σ_h:σ_v:=45:30:40MPa



(b)σ_H:σ_h:σ_v:=35:20:30MPa

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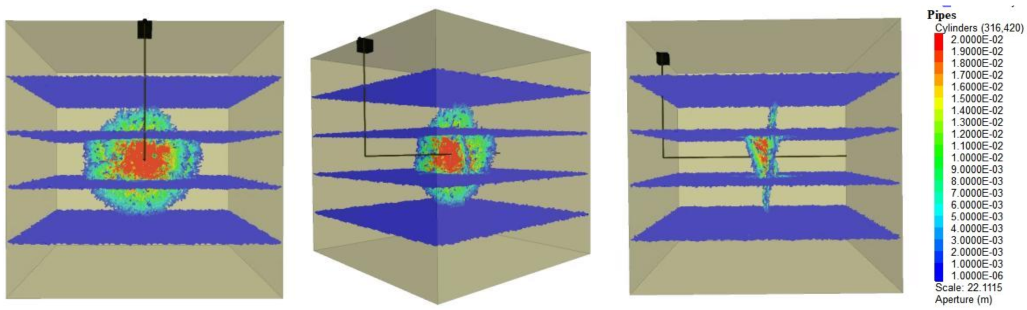
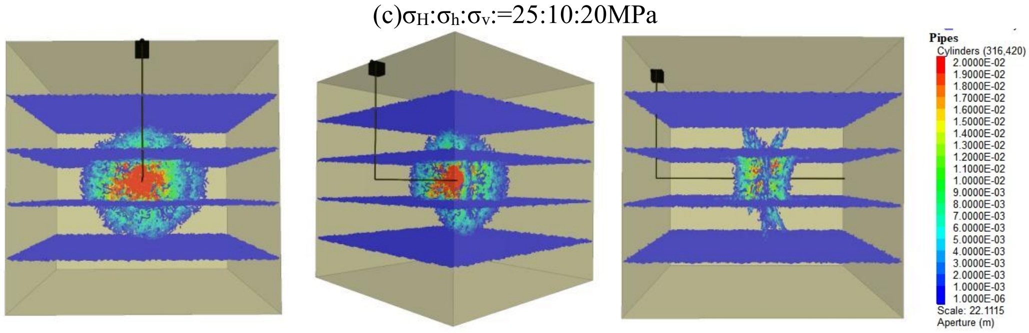


(c)σH:σh:σv:=25:10:20MPa

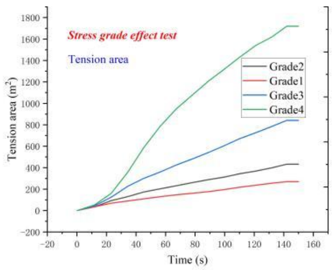


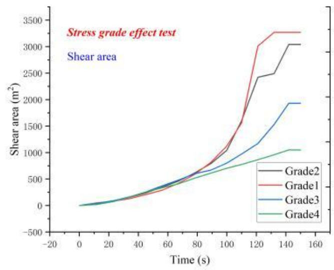
(d)σH:σh:σv:=15:2:10MPa

Fig. 1 Test result chart

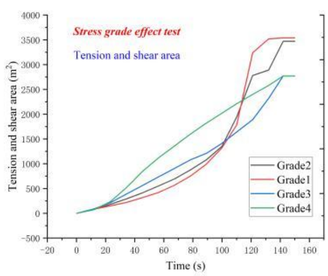
The figure shows the test results obtained by Xsite . As can be seen from the figure, with the decrease of stress grade, the most obvious feature is that the number of branch cracks increases significantly. When the triaxial stress is $\sigma_H:\sigma_h:\sigma_v$:=45:30:40MPa, there is only one hydraulic fracture, but the shale face is opened and communicated by the hydraulic fracture. When the triaxial stress is $\sigma_H:\sigma_h:\sigma_v$:=35:20:30MPa, branch cracks begin to appear. When the triaxial stress is $\sigma_H:\sigma_h:\sigma_v$:=15:2:10MPa, four hydraulic cracks appear. Therefore, it can be seen that the high stress grade has a certain binding effect on the fracture propagation direction, while the low stress grade is conducive to the construction of the fracture network.

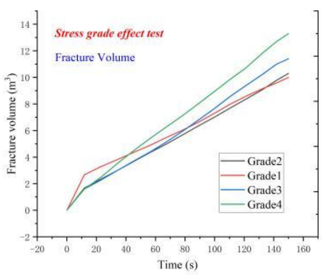
4. Discussions





(a)Tensile fracture area (b)Shear fracture area





(c)Total fracture area (d)Fracture volume

Fig. 2 Stress grade - fracture characteristic parameters

The picture shows stress gradation-crack characteristic parameters. It can be seen from Figure (a) that the tensile crack area and crack volume increase with the decrease of stress grade, as shown in Figure (d). This is consistent with the experimental phenomenon. However, the shear crack area under the action of high stress grade is larger, as shown in

Figure (b). The final total fracture area is still larger at high stress levels, as shown in Figure (c), indicating that the shear fracture area is higher than the tensile fracture area due to the presence of the bedding surface. It also proves that the key to the formation of complex fracture network in shale reservoir is to make good use of the multilayer characteristics of shale.

5. Conclusions

In this paper, by means of simulation, four stress levels are set under the premise of constant stress difference to study the effect of depth change on hydraulic fracture characteristics of shale reservoir. The following conclusions are drawn:
a. According to the three-dimensional diagram of Xsite test results, it is found that low stress levels are conducive to the construction of fracture network, while high stress levels can control the propagation direction of hydraulic fractures, and high stress levels are conducive to the communication of hydraulic fractures' bedding planes.
b. The analysis of the characteristic parameters of cracks shows that the area of tensile cracks is larger at low stress levels, while the area of shear cracks at high stress levels is larger. The crack volume is larger at low stress grade and the total crack area is larger at high stress grade
c. The key to the formation of complex fracture network in shale reservoir is to make good use of the multilayer characteristics of shale. This conclusion can provide reference for on-site hydraulic fracturing.

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