# Rock Fracture Analysis Method in Drilling Operation

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**Abstract.** In the course of drilling operation, the failure of fracture pressure prediction often leads to accidents such as blowout accident, well leakage accident, well deviation accident, wellbore collapse accident, pipe sticking accident, and so on. For deep well drilling operation, the prediction of fracture pressure is very important to the selection of drilling fluid and the stability of the wellbore. A rock fracture analysis method is presented in this paper, which can be used to improve the safety of drilling operations. Firstly, the prediction model of fracture pressure is established. Secondly, the fracture process of carbonate rocks in east Sichuan area is simulated and analyzed by using RFPA-2D software. Finally, on the basis of the above experiments and analysis, the measures to improve the safety of drilling operation are put forward. This method provides a basis for the selection of crushing mode and the rational combination of crushing parameters in the drilling operation and has a good guiding significance for improving the safety of drilling operation.

**Keywords:** Drilling operation · Rock fracture analysis · RFPA-2D software · Rock fracture experiment · Safety measures


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## 1 Introduction

In the process of drilling operation, accidents which threaten the safety of drilling operation was easy happened, such as gas blowout accident, well leakage accident, well slope accident, hole collapse accident, pipe sticking accident, and so on. All of these accidents are often associated with the failure to predict rupture pressure. For deep well drilling operation, the prediction of fracture pressure is very important to the selection of drilling fluid and the stability of borehole wall.

The key of drilling safety is the selection of drilling fluid and the prediction of fracture pressure, the prediction of formation fracture pressure is inaccurate, which will affect the selection of drilling fluid. If the drilling fluid pressure is too high, it is easy to have a well leakage accident. If the drilling fluid pressure is too low, it is easy to have a blowout accident. These accidents will cause unestimated losses. In the aspects of the stability of the well wall, the greater difference between the maximum principal stress and the minimum principal stress, the more likely an accident will occur. So it is very important to predict and analyze the fracture scale and the degree of fracture of rock in drilling operation.

## 2 Analysis of Rock Fracture

In this paper, the fracture process of carbonate rocks in east Sichuan is analyzed. According to the three dimensional in situ stress model, mechanism of strata fracture and the combination of carbonate formation of low hole, anisotropy and heterogeneity, rock mechanics characteristics and so on, the formation of fracture pressure which is suitable for carbonate section is:

$$p_{\mathrm{f}} = \alpha P_{\mathrm{p}} + \mu_{\mathrm{b}} \frac{\mu}{1-\mu}\left(P_0 - \alpha P_{\mathrm{p}}\right) + \mathrm{C}_1\mathrm{C}_2 S_{\mathrm{t}} \tag{1}$$

The first item in Eq. (1) reflects the influence of formation pore pressure on fracture pressure, the second part in Eq. (1) reflects the contribution of vertical skeleton which caused by the combination of overlying strata pressure and formation pore pressure stress to fracture pressure, the third part in Eq. (1) reflects the influence of tensile strength of rock on fracture pressure, and the coefficients in front of the $P_{\mathrm{p}}$, $(P_0 - \alpha P_{\mathrm{p}})$, $S_{\mathrm{t}}$ reflects the magnitude of their effect on the fracture pressure.

In Eq. (1):

$P_{\mathrm{f}}$ formation fracture pressure, MPa;
$P_{\mathrm{p}}$ formation pore pressure, MPa;
$P_0$ overburden pressure, MPa;
$\mu_{\mathrm{b}}$ the non-equilibrium factor of the formation in skeleton stress (dimensionless);
$\mu$ rock Poisson ratio;
$\alpha$ Biot coefficient;
$S_{\mathrm{t}}$ rock tensile strength;

$C_1 = 1$ indicates non-crack resistance formation or porous reservoir, otherwise $C_1 = 0$;

$C_2 = 1$ indicates that the fracturing pressure is calculated for fracturing construction. $C_2 = 0$ indicates that the tensile strength of the formation should be neglected in order to prevent the leakage in the drilling from causing by excessive gravity mud.

## 3 The Prediction Model of Fracture Pressure

Now we establish the fracture pressure prediction model: In the drilling process, the underground rock is subjected to the *x*-direction confining pressure and the *y*-direction load. In combination with the actual loading method, both the lower boundary and the right boundary are fixed constraints, the upper boundary is fixed and loaded, the left boundary is controlled by the confining pressure variables. Establishing a grid $100 \times 100$, an area of $1000 \times 1000(\text{mm}^2)$, then, control the size of the pressure variable in the *x*-direction, the fixed *y*-direction load is 10 MPa and observes the maximum principal stress changes. Because the profile of the model is horizontal, it will be subjected to the confining pressure. Then the increment of confining pressure in *X*-direction is 0.001 MPa and the initial value is 5 MPa, the maximum principal stress is used to simulating the minimum pressure of fracture.

The model is shown in Fig. 1. The rock parameters are shown in Table 1.

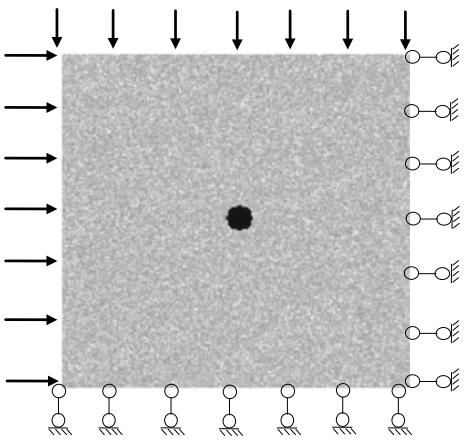

**Fig. 1.** Schematic diagram of the model

**Table 1.** Rock mechanics parameters

| Parameter name | Rock |
|---|---|
| Elastic modulus(E/GPa) | 2,6,8 |
| Homogeneous degree | 2 |
| Tensile strength(MPa) | 50 |
| Friction angle(°) | 30 |
| Passion ratio | 0.25 |
| Permeability coefficient | 0.01 |
| Solid-liquid coupling coefficient | 0.2 |
| Pore pressure coefficient | 0.5 |
| Porosity | 0.1 |

# 4 The Simulation Experiment of the Process of the Rock Burst

RFPA software is a rock fracture process analysis system based on elastic mechanics as stress analysis tool, elastic damage theory and modified Coulomb failure criterion as medium deformation and failure analysis module. In this paper, based on the characteristics of oil and gas reservoirs in east Sichuan and related mechanical parameters of carbonate rocks, the rock fracture process is simulated by RFPA-2D software.

## 4.1 The Characteristics of Oil and Gas Reservoirs in Eastern Sichuan

The rocks in the east of Sichuan are mostly carbonate rocks. It is mainly composed of dolomite and limestone and complicated with stratigraphical structure, these characteristics make it difficult to predict the pressure and accidents such as well leakage and wall collapse often occurred in the course of drilling.

## 4.2 The Simulation Experiment

The followings apply the RFPA-2D software to simulate the fracture scale, maximum principal stress and acoustic emission of the carbonate rock fracture process in east Sichuan region, the maximum principal stress is approximately equal to the formation fracture pressure.

In the six experiments we did, the *y*-direction load is 10 MPa, in the *x*-direction, the confining pressure is 5, 10, 15, 20, 25, 30 MPa, and the confining pressure increment is 0.001 MPa.

Experimental results: the maximum principal stress of the six experiments is shown in Fig. 2, the acoustic emission is shown in Fig. 3, and the elastic modulus is shown in Fig. 4. The experimental data are shown in Table 2.

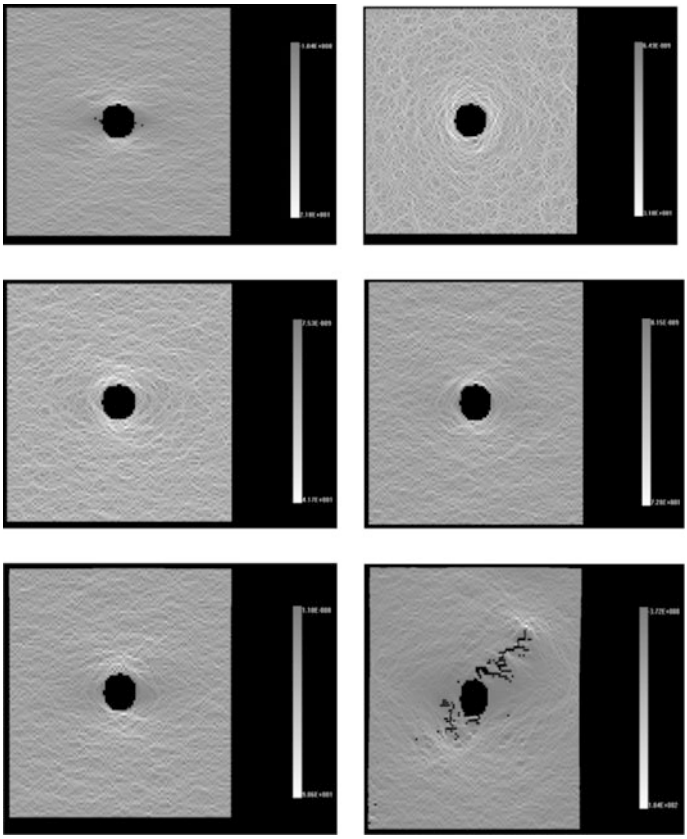

**Fig. 2.** Maximum principal stress

The maximum principal stress of experiment 6 exceeds the limit stress of rock fracture, macro-damage occurred, sound emission is obvious, and it is very dangerous. When the drilling operation continues, the maximum principal stress reaches 184 MPa, the acoustic emission is obvious, and the rock appears macro-damage.

### 4.3 The Analysis of Experimental Results

(1) The analysis of maximum principal stress
The figure of the maximum principal shows that when load is fixed and the confining pressure is increased, a slight macrofracture occurred near the initial borehole,then the surrounding stress field is changed, and the minor fissures are constantly produced, expanded and formed into fissures. With the increase of

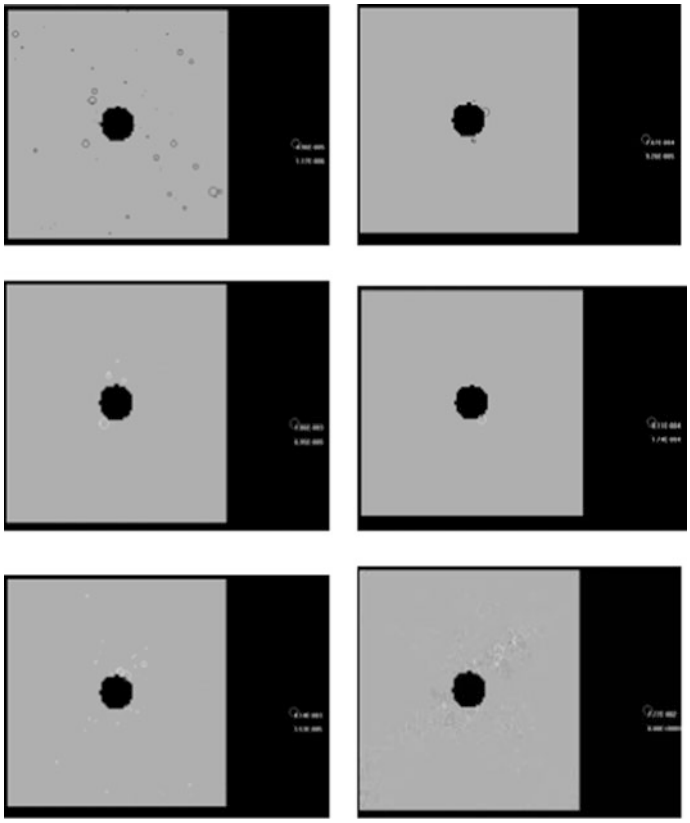

**Fig. 3.** Acoustic emission

confining pressure, the macro-damage was formed at the upper right. The above simulation experiment shows that in the process of drilling especially in the process of deep drilling, with the increase of confining pressure, the rock probably experienced three processes: the appearance of microcracks, the expansion of cracks and the appearance of macrocracks, the breaking form of rock is changed from brittle failure to plastic fracture.

(2) The analysis of acoustic emission

The figure of the acoustic emission shows that when the maximum principal stress reaches a certain value, the microfracture will occur inside the rock, and the strain energy accumulated in the rock mass is released, and the energy is spread out in the form of transient elastic wave. Acoustic emission is caused by the generation

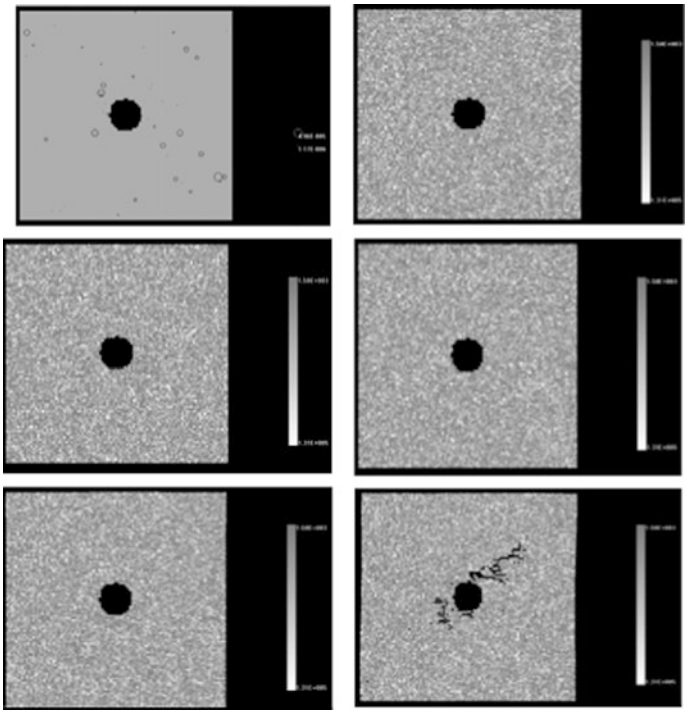

**Fig. 4.** Elastic modulus

**Table 2.** Experimental data table

| Experiment | Maximum principal tress (MPa) | Measured formation pore pressure (MPa) |
|---|---|---|
| 1 | 21.8 | 30.595 |
| 2 | 31.0 | 30.595 |
| 3 | 41.7 | 45.409 |
| 4 | 72.8 | 66.22 |
| 5 | 90.6 | 77.57 |

and development of internal cracks and friction between internal particles. In the initial stage of loading, due to the large porosity of the rock, the loading process is compacted; the acoustic emission generated is serious. With the further loading and increasing stress, the acoustic emission intensifies again until the macrofracture occurs, so experiment 3 can be used as a turning point. After the experiment 3, the rock will have macro-damage, it is very dangerous.

## 5 The Conclusion of Experiment

The above experiments have shown that the soft rock is continuously compacted, the hole is shrunk and the difference between the minimum stress and the maximum stress is increasing in the continuous process of drilling. When the difference between the minimum stress and the maximum stress of the borehole rock is bigger, the problem such as the collapse of the well and the collapse sticking are more prominent. If the drilling fluid density is too small, some soft rock will produce shear stress and collapse; if the drilling fluid density is too big, it will rupture the bottom layer, and the fracture pressure at the bottom will depend on the stress state on the borehole wall.

## 6 The Safety Measures for Drilling Operations

(1) In the process of going down, if it is found that the wellhead does not return to the mud or the reverse mud is sprayed in the drill pipe, it should stop drilling immediately; open the pump circulates well or draw the eye, until the downhole is normal resume the drill.
(2) In the process of pulling out, if it is found that the wellhead drops or the drill pipe is in reverse, the pulling out should be stopped immediately. Open the pump cycle, when the pump pressure is normal, the well is unobstructed, and the pressure inside and outside the pipe is balanced, then the pulling out is resumed. If the recovery cycle is hopeless, the drilling tool is still active; it should be pulled out immediately. Although there is a lot of resistance at this time, the drill rod is still spraying; we cannot wait at all. As long as the safety load of the equipment and drilling tools is within, it should be pulling out as far as possible.
(3) After the well collapse, the circulating cuttings cannot be taken out, and the following measures can be adopted: using high yield drilling fluid to keep the annular laminar flow state; using high concentration sand carrying liquid to wash well; enlarging the drill hole to increase the displacement; the high viscous cut drilling fluid is injected into the collapse well before pulling out.

## 7 Conclusion

Rocks show the anisotropy during the fracture process. In the actual drilling process, choosing the right drilling fluid density is very important. The prediction and analysis of the formation pressure and the possible rupture scale provide the basis for the selection of the crushing mode and the reasonable combination of the crushing parameters in the drilling process and also provide a guarantee for the safety and efficiency of the drilling process.

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## Author Biography

**Zhaomei Xue** (1969–), female, Master of Engineering, associate professor, mainly engaged in teaching and research work on oil and gas safety engineering.