Energy Engineering and Environmental Engineering

Part 2

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Tahe Oilfield Ground Stress Analysis Model and its Application in the Barefoot Hole Wall Collapse

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Abstract. The T606 well in Tahe oilfield, deep core sample physical mechanical properties were tested to provide the experimental theoretical basis for casing failure analysis under the stress field. Afterwards, established the Tahe oilfield ground stress model based on the increasing fracturing data and related field ground stress models. The ground stress model is applied to calculate the critical level value of barefoot hole wall collapse in Tahe oilfield six and seven area. By regulating the production parameters and keeping borehole liquid level height above the critical level value, open hole collapse can be prevented.

Introduction

Nowadays ground stress is widely used in petroleum engineering activity, which can predict and diagnosis the possibility of casing damage in the formation or the interval according to the certain stress size. Therefore, it could provide supports for further study of the casing stress calculation. At the same time, ground stress is also the foundation data of the oil-field development project design, the analysis of hydraulic fracturing crack propagation law, the prediction of the formation fracture pressure and the formation collapse pressure. So, getting accurate information of stress as soon as possible is of great significance for oil and gas exploration and development.

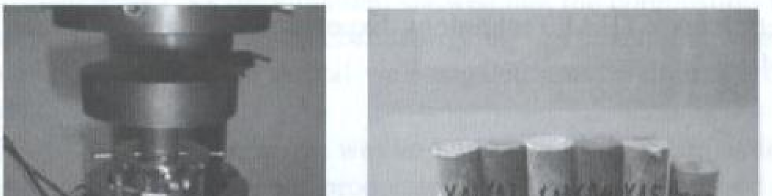

Figure 1 Triaxial compression test equipment and sample

1 Physical and mechanical property test of TaHe oilfield reservoir rock

Reservoir rock physical and mechanical properties including the poisson's ratio and elastic modulus, bulk modulus, shear modulus, etc., which provide basic data and the theoretical basis for deep ground stress test analysis, stress field simulation evaluation and sidewall stability analysis. It has an important significance of guiding oil and gas exploration.

In this paper, with the reservoir rocks of T606 well in TaHe oilfield 6 area, whose core sample average depth is 5184.5 m , as the test sample for contrast test of rock physical and mechanical properties. Finally get the related characteristics of rock TaHe oilfield data (Table 1). the United States GCTS company rock comprehensive test system is used both for Single axis compression test and the triaxial compression test(Fig.1).

Table 1 T606 well rock physical and mechanical properties test results summary

Test project	test index		sandstone in Immersion
Single axis compression test	Rock single axis compressive strength σ1(MPa)		46. 26
	modulus of elasticityE (×104MPa)		0. 882
	poisson ratio μ		0. 366
triaxial compression test	σ3=60MPa	Axial failure stress σ1(MPa)	324. 56
		modulus of elasticityE(×104MPa)	2. 806
		poisson ratio μ	0. 245
Shear strength parameters calculation	Zero confining pressure regression strength σ0 (MPa)		70. 68
	Fitting k value of formula		4. 46
	cohesion C (MPa)		15. 10
	internal friction angle φ (°)		40. 19

According to the test data calculation related data:

Uniaxial compression test $\sigma = P/A$ (1)

Triaxial compression test
$$\begin{cases} \sigma = \sigma_1 - \sigma_3 \\ E = (\sigma_1 - \sigma_3)_{(50)} / \varepsilon_{h(50)} \\ \mu = | \varepsilon d_{(50)} / \varepsilon h_{(50)} \end{cases} \tag{2}$$

shear strength
$$\begin{cases} C = \dfrac{\sigma_0}{2\sqrt{K}} \\ \phi = tg^{-1}((K-1)/(2\sqrt{K})) \end{cases} \tag{3}$$

2 The stress model establishment and application of TaHe oilfield

Despite having many stress calculation models [1, 2], most of those are empirical. Different parts of the ground should choose different model, and between models always have obvious difference (Table 2). According to the relational expression of the vertical stress and the depth listed in the table about some oilfield, we can see: Vertical stress value range in the near 0.021 H, so TaHe oilfield vertical stress can approximate think as σ_v=0.021H.

Table 2 The relation of ground stress and depth in same oilfield

Oilfield	σ_H (Mpa)	σ_h (Mpa)	σ_v (Mpa)
LiaoHe Oilfield (497～3473m)	-2.34+0.0266H	-0.777+0.0182H	0.021H
DaGang oilfield (0～4000m)	0.7+0.023H	0.5+0.018H	0.021H
HuaBei oilfield (1500～2000m)	-10.5+0.03H	-5.87+0.021H	0.021H
ShengLi Oilfield (1300～3300m)	-22.58+0.034H	-11.65+0.022H	(0.021～0.022)H
ZhongYuan Oilfield(1830～3881m)	-27.1+0.036H	-16.6+0.024H	0.022+0.026H

2.1 Horizontal ground stress model of TaHe oilfield

Liang Lixi collected datas of 15 Wells in TaHe oilfield on fracture stimulation [3] , and based on which testing analysing the stress value of deep 5440 to 6100 meter. The result of linear regression analysis as fig.2 show.

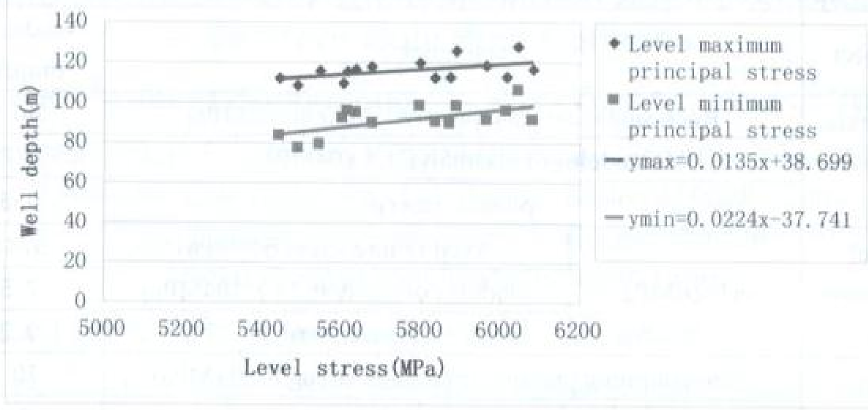

Figure 2 The change rule of principal stress in TaHeoilfield deep level

(1) horizontal maximum principal stress change from 108 to 129MPa, the rate of change with depth is 1.920～2.140Mpa/100m; Level minimum principal stress is 77.0～107.0Mpa; the rate of change with depth is 1.412～1.756Mpa.

(2) The ratio of horizontal maximum principal stress to horizontal minimum principal stress is 1.185～1.402. Compared with three principal stress (σv, σH, σh) of the same test point will know: On the interval range depth of analysis ground stress type are σv≧σH≧σh.

Table 3 TaHe oilfield ground stress

Oilfield	Formation depth /m	σ_H (MPa)	σ_h (MPa)	σ_v (MPa)
TaHe Oilfield	0-4000	0.7+0.023H	0.5+0.018H	0.021H
	4000-5440	0.0135H +38.7	0.00876H+36.46	
	5440-6100	0.0135H+38.699	0.0224H-37.741	

Through the calculation of actual, found the stress size calculated based on DaGang oilfield horizontal ground stress model is close to the datas of TaHe oilfield on fracture stimulation, get the relational expression of level maximum and minimum principal stress in TaHe oilfield (Table 2):

2.2 The application of TaHe oilfield ground stress model

Casing failure using Mohr-Coulomb criterion establish open hole collapse mechanics model. Combined TaHe oilfield ground stress model and reservoir rock physical and mechanical performance mentioned above, and forecasting the liquid level height when open hole collapse.

Wall mechanical model here is directly used the formula in material[4]. According to the principal stress formula, wall three principal stress component is:

$$\begin{cases} \sigma_1 = \sigma_r = P_i \\ \sigma_2 = \dfrac{\sigma_\theta + \sigma_Z}{2} + \dfrac{\sqrt{(\sigma_\theta - \sigma_Z)^2 + \tau_{\theta Z}{}^2}}{2} \\ \sigma_3 = \dfrac{\sigma_\theta + \sigma_Z}{2} - \dfrac{\sqrt{(\sigma_\theta - \sigma_Z)^2 + \tau_{\theta Z}{}^2}}{2} \end{cases} \quad (5)$$

Mohr-Coulomb criterion holds that the destruction of the material is mainly shear failure. When shearing stress on the bevel of a material reach or exceed the sum of the cohesive force and frictional resistance on the damage surface, it will cause the material shear slip along the slope failure. The relationship between the shear strength and the normal stress as follows:

$$\begin{cases} \tau_f = c + \sigma \tan\varphi \\ \sigma = \dfrac{\sigma_1 + \sigma_3}{2} + \dfrac{\sigma_1 - \sigma_3}{2}\cos 2\theta \\ \tau = \dfrac{\sigma_1 - \sigma_3}{2}\sin 2\theta \end{cases} \quad (6)$$

In which

σ_1-maximum principal stress （MPa） σ_3-minimum principal stress （MPa） ;

$\varepsilon h(50)$ — $\sigma 1(50)$ axial compression strain; $\varepsilon d_{(50)}$—$\sigma 1(50)$radial compressive strain;

τ f—the shear strength on shear plane; c-cohesive force, C =15.10(MPa);

σ -the direct stress of shearing surface; ψ -internal friction angle, =40.19° ;tan2 θ =-1/ μ .

In order to avoid the wall collapse, it must meet $\tau < \tau$ f .

Table 4 Liquid level height prediction of TaHe oilfield well collapse collapse

well number	TK649	TK602	TK665 CH	TK678	TK659	TK730	TK764	TK770	Average
Well depth/m	5700	5696	5700	5606	5605	5661	5600	5660	5653.5
Critical level/m	2312	2316	2312	2398	2398	2349	2404	2348	2354.625
Note: critical level is refers to the open hole collapse level from the depth of the well head count									

Therefore, solving the critical level value of casing damage only need to express internal pressure in oil Wells with the liquid level height. Let TaHe oilfield 8 well serve as an example, the calculation results shown in table 4.

3 Conclusion

This paper connect casing damage with the link level height within well, based on the general model for stress, calculating the liquid level position of oil well when casing damage.(1) This paper through the experiment, determined some related geological factors of TaHe oilfield. And then, combined with Liang Lixi statistics data of geostress on TaHe oilfield, preliminary obtained the stress model.(2) Applied the stress model in calculating critical level value of oil well casing damage.(3) Through adjusting and controlling production parameters, make sure the borehole level not less than critical level height, and it have the effect of prevention wall damage.

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