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Test of Annular Pressure Relief And Pressure Recovery in Gas Wells

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Abstract

With the development of oil and gas exploration and development, the problem of annulus pressure becomes more and more serious. In this paper, the wellbore pressure field is established. In view of the serious problem of annulus pressure in Moxi block, the annulus pressure relief experiment is made. According to the experimental results and relevant standards, the cause of annulus pressure in this well is determined, which provides guidance and suggestions for the subsequent production.

Keywords

Pressure field; Annulus pressure; Pressure relief experiment.

1. Introduction

With the development of oil and gas exploration and development, the problem of annulus pressure becomes more and more serious. According to relevant statistical data, most of the oil and gas wells in the outer continental shelf of the United States have annulus pressure phenomenon. There are 11498 annulus pressure casing sections in 8122 wells, and 50% of them occur in the annulus between production casing and tubing. Annulus pressure is one of the key factors that affect the normal production of oil and gas wells. Too much annulus pressure will lead to wellhead lifting, casing damage and other problems. For high sulfur gas wells, it may also cause serious casualties, environmental pollution and economic losses. Therefore, it is of great significance to explore the causes of annulus pressure to ensure the integrity of the string, improve the safety of the wellbore and extend the mining life [1-6].

In 1986, enrich f. klementich concave et al [7]. Accurately calculated the stress load of the casing according to the casing in different service stages, designed the casing string through stress analysis, and saved the casing steel to the maximum extent under the safe production conditions of the whole production cycle of oil and gas wells. The stress analysis in this paper mainly considers the triaxial stress analysis under the condition of pressure in the annulus, and then checks and analyzes the casing's resistance to external extrusion, internal pressure and tensile strength. In 1991, A. Adams et al [8]. Studied and analyzed the strength design of casing string under the condition of thermal expansion effect of annulus fluid. The results show that the thermal expansion of the annulus fluid will produce high annulus pressure, which can not be ignored in the strength design of the casing string. The stress state of the whole casing string in different production stages needs to be analyzed (SLA). In 1994, A.S. halal et al [9]. Simplified the casing string in the formation into a composite finite element cylinder, made a comprehensive analysis of the casing string design under the condition of annulus pressure, and established the stress analysis model of the casing string under the annulus pressure. Through the comparison of model calculation, it is found that the annular pressure calculated by the flexible single pipe model is lower than that calculated by the rigid string model. In 2014, Siva rama[10] and others proposed a method based on finite element simulation to predict the influence of annular pressure on wellbore materials. In this paper, a multi-level borehole

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simplified model is established, by which the action point and direction of the load generated by the annulus pressure are determined, and the performance of traditional cement and elastic cement, P110 casing and N80 casing under the condition of pressure is compared. It is found that elastic cement can better position the casing under the condition of pressure, and the reliability of high-strength casing is high.

Since 2009, the research on annular pressure of gas wells in China has gradually increased. In 2013, according to API RP 90 and NORSOK d-010, Li Lili et al [11]. Determined the calculation method of the maximum and minimum allowable annular operating pressure applicable to high pressure gas wells in Tarim Oilfield by referring to the international well integrity general method, which has certain promotion significance for the annular safety pressure monitoring and management of high pressure gas wells. In 2014[12], in his dissertation, Wu Yan proposed a mathematical model of annulus pressure based on seepage theory, considering the gas leakage of cement sheath and the leakage of micro gap between cementation surfaces, and finally gave a calculation method of annulus pressure to ensure the safety of wellhead pressure. In 2016[13], Zhu Hong equally established a mathematical model of annular pressure with different initial gas channeling flow and gas cap volume under stable conditions, and carried out indoor experiments to simulate the process of pressure relief and pressure recovery. Finally, based on dimensional analysis theory, the empirical formula of pressure recovery was summarized by using mathematical optimization software, providing a reference for the pressure management and control of annular a. According to the relevant standards at home and abroad, Yang Zhou [14] established a multi parameter annulus pressure monitoring and diagnosis method, analyzed the causes of annulus pressure, calculated the maximum allowable value of annulus, diagnosed and analyzed the annulus pressure, and finally established a complete set of equipment for surface detection of annulus pressure for offshore oil and gas wells. In 2017[15], Xue Shuai, based on the volume multi-scale coupling and licensing method, established the temperature field and pressure field of high-temperature and high-pressure gas wells, and gave the safety evaluation method of casing strength considering the factors such as annular pressure of gas wells.

The wellbore structure of high temperature and high pressure well is usually composed of multi-layer casing. In cementing operation, according to the actual conditions and cost considerations, the cementing cement between casing layers does not flow back to the wellhead, and multiple annular spaces will be formed between casing layers. According to the relevant regulations of nosokd 1010h and api90, the annular space between the tubing and the production casing is usually called as a annulus, the annular space between the production casing and the technical casing is called as B annulus, and the annular space between the technical casing and its adjacent upper casing is called C annulus.

The annular pressure is usually divided into continuous annular pressure, thermal induced pressure and external pressure. Continuous annular pressure (SCP) refers to the phenomenon that the annular pressure at the wellhead recovers to the level before pressure relief within a certain period of time after pressure relief and other operations. There are four main reasons for annular pressure of oil and gas wells:

(1) Annulus pressure caused by various human factors (including monitoring annulus pressure, thermal production management, gas lift or other purposes): for other reasons, it is necessary to apply pressure to casing annulus, such as gas lift, etc.

(2) poor cementing quality, poor consolidation of casing and cement, fluid channel between casing and cement, and annulus pressure caused by gas seepage caused by micro fracture of cement sheath.

(3) Failure of completion string and aging failure of completion tools: failure of casing string body of oil and gas well, especially failure of screw connection, and annulus pressure caused by gas channeling caused by failure of rubber aging seal of packer.

(4) The results of the thermal expansion of the liquid in the pressure annulus. When oil and gas wells are in production, plugging or shut down, the annulus temperature and volume will be changed, which will cause the annulus fluid to expand, and then the annulus pressure will be produced.

The sustained annulus pressure is usually caused by the leakage of the wellbore barrier unit that makes the fluid flow through the well barrier and enter the annulus, such as: tubing leakage, packer leakage, poor cementing quality, etc. Continuous annulus pressure may come from any pressure bearing formation, such as oil and gas reservoir.

2. Establishment of Wellbore Pressure Field

The distribution of pressure in the wellbore directly affects the stress and deformation analysis of the completion string, but the pressure field is not constant in the whole life cycle of the well. If the fluid has energy output or external force to do work, the pressure distribution will change. Therefore, the model should be based on the following assumptions;

(1) the gas is in - dimensional stable flow in the well profile:

(2) vertically, there is only fluid heat transfer in the tubing:

(3) in the same depth section, the physical parameters of fluid are equal everywhere.

According to the analysis of the flow law of the fluid in the wellbore, the total pressure gradient of the fluid is composed of three parts: acceleration pressure gradient, gravity pressure gradient and friction pressure gradient

$$\frac{dp}{dz} = \left(\frac{dp}{dz}\right)_a + \left(\frac{dp}{d_z}\right)_h + \left(\frac{dp}{d_z}\right)_f \tag{1}$$

$$\frac{dp}{dz} = \left(\frac{dp}{dz}\right)_a + \left(\frac{dp}{d_z}\right)_h + \left(\frac{dp}{d_z}\right)_f \tag{2}$$

Among them, acceleration pressure gradient: $\left(\frac{dp}{d_z}\right)_a = \frac{d\left(pv^2\right)}{2}$

Acceleration of gravity: $\left(\frac{dp}{d_z}\right)_h = pgdz\cos\theta$

Friction pressure gradient: $\left(\frac{dp}{d_z}\right)_f = f\frac{pv^2}{2d_n}dz$

$$dp = -\frac{pd\left(v^2\right)}{2} - f\frac{pv^2}{2d_n}dz - pgdz\cos\theta \tag{3}$$

Where: $p-$ wellbore pressure, MPa;

ρ -Fluid density in tubing, g/cm^3

v -Fluid velocity in tubing, m/s
g -acceleration of gravity, m/s^2
z -tubing length, m
θ -Well angle, °
f -friction coefficient, dimensionless
d_n -Inner diameter of oil pipe, m
The density of fluid in the model can be derived from the equation of state of gas

$$\rho = \frac{pM}{Z_g RT} = 3484.8\gamma \frac{P}{Z_g T} \tag{4}$$

Where: M -molar mass of gas, kg
z_g -Gas compression factor, dimensionless
R -General gas constant
The fluid velocity in the tube is expressed as

$$v = Bv_{st} = z_g \frac{T}{293} \times \frac{0.101325}{P} \times \frac{Q_{st}}{86400} \times \frac{4}{\pi d_n^2} = 5\times 10^{-9} \frac{Q_{st} Z_g T}{d_n^2 p} \tag{5}$$

Where: B -gas volume coefficient, dimensionless
v_{st} -Gas flow rate at standard conditions, m/s
Q_{st} -Production at standard conditions, m^3/d

Order: $C_1 = 5\times 10^{-9} Q_{st} / \mathrm{d}_{ti}^2$, $C_2 = 34.84.48\gamma, \mathrm{C}_3 = Z_g T / P$ obtain that:

$$\mathrm{d}p = -10^{-6} \times \left(C_1^2 C_2 dC_3 + \frac{C_2 g \cos\theta}{C_3} dz + \frac{f C_1^2 C_2 C_3}{2d_n} dz \right) \tag{6}$$

By using the idea of micro element method, the wellbore is divided into several small sections, in which the length of each section is
The line integral solution is obtained, and the calculation formula of the gas pressure at the outlet of each section is

$$p_{out} = p_{in} - \left[C_1^2 C_2 \left(C_{3out} - C_{in} \right) + \frac{C_2 g \Delta z \cos\theta}{2} \times \left(\frac{1}{C_{3out}} + \frac{1}{C_{3in}} \right) + \frac{\Delta z}{2} \frac{f C_1^2 C_2}{2} \left(C_{3out} + C_{3in} \right) \right] \times 10^{-6} \tag{7}$$

3. Case Analysis

The Longwangmiao formation gas reservoir in Moxi block belongs to the local structure in Central Sichuan. Because it is located in the center of the basin, the squeezing pressure from the periphery of the basin becomes very weak here, mainly affected by the gentle uplift of the basement, thus forming some low-level structures with multiple formations and multiple highs.

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The main axis direction is mostly NE direction, parallel to the paleouplift, and the structure is not obvious, while the deep structure is relatively obvious, and the fault is not developed. Gaoshiti anpingdian Moxi buried structural belt is the largest composite structure among many structures. Gaoshiti anpingdian Moxi buried structural belt is one of the three anticline structural belts found in Leshan longnusi ancient uplift area, namely Weiyuan structure, Gaoshiti anpingdian Moxi buried structural belt and panlongchang buried structural belt. It is longnusi structure in the East, Ziyang ancient trap and Weiyuan structure in the southwest.

In Moxi block of central Sichuan gas field, well is 5380m deep and is sealed by MHR packer. The depth of setting is 4463m. The method of clear water + protective fluid is adopted in the annulus to protect the pipe string from corrosion. The main production layer is group 4 of Longwangmiao combined lamp. The depth of surface casing, technical casing, production casing and tail pipe is 504m, 3249m, 5044m and 5380m respectively. The outer diameters of tubing, technical casing, production casing and tailpipe are 406.4mm, 311.20mm, 215.90m and 149.20mm respectively.

According to the daily production data of 45 gas wells in the block, 40% of the oil pressure of production wells in the block is between 40-50mpa, of which 2 wells with production oil pressure higher than 50MPa belong to high-pressure production; the technical / oil pressure is mainly concentrated in the 10-20Mpa range, but 20% of the oil and gas wells are still between 20-30Mpa, and the casing pressure distribution is relatively uniform, accounting for 16% above 30MPa. The annular pressure of gas wells in this block is relatively prominent, and the number of gas wells with high annular pressure is large, including a few wells with high annular pressure, so it is urgent to diagnose the annular pressure and determine the cause of the pressure.

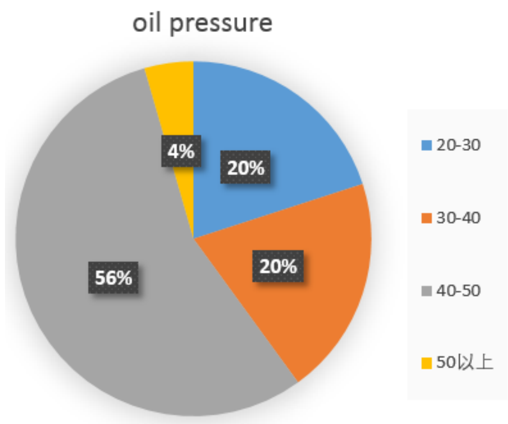

Fig 1. Oil pressure

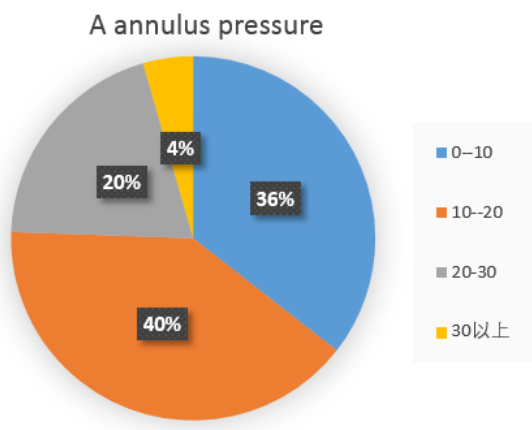

Fig 2. A annulus pressure

According to the test process, field test is carried out for Moxi well x, and pressure monitoring is carried out through the pressure relief pipeline of the gas production tree. The overall layout of the field gas production tree and the relief pipeline are as shown in the figure:

Fig 3. Overall diagram of gas production tree

Fig 4. Pressure relief pipeline

In order to judge the sealing condition of production casing and casing head, the field was organized to carry out pressure relief test on B annulus, and the test process was as follows:

(1) Use od pipe to continuously discharge the pressure of annulus B for 24 hours, and observe and record the pressure of annulus a and annulus B under the state of discharge. When the pressure of annulus B changes greatly in the initial stage, it is recommended to record the pressure data of annulus a and annulus B every 0.5 hours; in the later stage, the pressure of annulus B is stable, and it is recommended to record the pressure data of annulus a and annulus B once in 1-2 hours.

(2) If the 24-hour B annulus pressure cannot be discharged completely, take the B annulus air sample for component analysis to determine the pressure source. Stop discharging 24 hours after releasing the b-annulus pressure, observe and record the recovery data of a and b-annulus pressure. The pressure of annulus a and annulus B of the well is tested for relief / recovery, and the recorded data is shown in the table below:

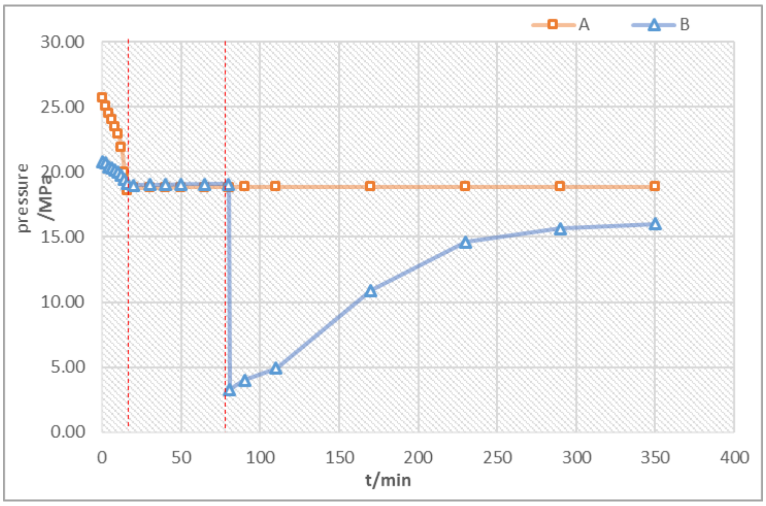

Fig 5. Test pressure change

Release the pressure of annulus a from 25.71 MPa to 18.82 MPa, and close the pressure relief process. In the stage of a annulus pressure relief, there is a slight drop in B annulus pressure, which belongs to normal pressure disturbance, and there is no change in C annulus pressure; in the stage of pressure recovery, there is almost no change in a annulus pressure within 24 hours, only 0.15 MPa increase.

When the B annulus pressure is released, the pressure of opening the relief valve drops rapidly, which drops to 3.30mpa in a few seconds. In order to avoid excessive outflow of protective fluid, the pressure relief process is closed, and there is no change in other annulus during this period.

It can be concluded that the pressure of annulus a and B mainly comes from thermal induced pressure, and there is no connection between the annuli. The combustible gas in the annuli may be caused by the original residual oil and gas in the annuli or slight leakage of completion string.

4. Summary

In this paper, referring to the previous research, the mathematical analytical model of annulus pressure is established. According to the actual production data of Moxi block, the test scheme is established and the pressure relief experiment is carried out. According to the experimental results, the annulus pressure in this block is mainly caused by the thermal force in the production process. In the production process, real-time monitoring should be carried out to ensure the safe production of oil and gas wells

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