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Study on enhancing oil recovery by CO2 injection in low permeability reservoir

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Abstract. The distribution characteristics of remaining oil in low permeability reservoirs are aimed at the quantity and distribution of remaining oil in the reservoir at the present stage, so as to take measures to exploit these remaining oil under reasonable economic and technical conditions, so as to improve recovery. The technology of carbon dioxide hubbing and pumping is to inject a certain amount of carbon dioxide into the reservoir under a certain pressure, stew the well for a period of time to make the carbon dioxide spread in the formation and miscible with the formation crude oil, and then open the well for production. At present, there are many methods to study residual oil at home and abroad, mainly including reservoir engineering methods such as logging method, core analysis method, numerical simulation, and dynamic analysis method using monitoring data and dynamic and static data of reservoir. Study the macro and micro residual oil distribution accurately using CO2 huff and huff technology to increase production.

Keywords: carbon dioxide flooding; Recovery rate; Remaining oil.

Low permeability reservoir has entered the high water cut stage, this study mainly relies on reservoir engineering and numerical simulation methods to carry out stable production potential analysis. According to the geological characteristics of different fault blocks, the remaining oil distribution characteristics are analyzed by means of dynamic analysis method, reservoir engineering method and numerical simulation, and the remaining oil potential of blocks and small beds is understood by making full use of the oilfield electrical measurement data, dynamic data, static data and monitoring data. Carbon dioxide flooding technology has been widely used abroad as an effective technology to improve the development effect of low permeability oilfield. The application of carbon dioxide miscible flooding technology widely used abroad has great technical and economic risks, while the carbon dioxide huff and huff oil production technology has a simple construction process, a wide range of reservoir application and a small technical and economic risk for effective production. Low permeability reservoir has great potential, which has been proved by the previous application effect through the research and production practice of low permeability reservoir, the pore throat of low permeability reservoir is smaller than the surface, and the permeability is low. Low permeability oil and gas fields have the characteristics of poor reservoir physical property, strong heterogeneity, small average pore throat radius, large specific surface, high capillary pressure and low permeability. Therefore, the development of low permeability oilfield cannot follow the traditional method of middle and high permeability oilfield development. Carbon dioxide huff and puff oil production technology has a good development effect, especially to effectively improve the development effect of low-production Wells in low permeability reservoirs, and has a wide application prospect.

1. Residual oil distribution study

As the oil field enters the high water cut development period, it is urgent to know the distribution of remaining oil in the reservoir of a single well and a region, search for potential oil layer, and adjust the operation plan. It is of great significance to study the qualitative identification and quantitative evaluation methods of waterlogged layer for improving the interpretation accuracy of waterlogged layer, clarifying the distribution law of remaining oil, and predicting the enrichment area of remaining oil.

1.1 Identification of flooded layer

The qualitative identification of waterlogged layer is to judge whether the oil layer is waterlogged or not according to the logging curve, and to indicate the level and level of waterlogged layer qualitatively. Generally, the method of "checking characteristics, comparing adjacent Wells and finding water source" is used to analyze and compare the reservoir and make comprehensive evaluation. The most basic change of reservoir waterflooding is the change of formation water resistivity and formation water saturation, so the variation law of resistivity and SP curve is used to judge the waterflooding layer and classify the waterflooding level. The typical characteristics of the flooded layer in the study area are SP curve baseline shift, GR curve tooth degree decreases and tends to be smooth, and resistivity decreases first and then increases in a "U-shaped" change with different development time.

The characteristics of SP baseline deviation: most of the injected water in the study area was fresh water (that is, the injected water resistivity Rwz> formation water resistivity Rw), and the SP baseline in the flooded area shifted in the negative direction. If the SP base line of a certain layer is offset, the upper part of the reservoir is flooded. If the base line of the lower part of SP is offset, it indicates that the lower part of the oil formation is flooded.

Resistivity variation characteristics: In the process of fresh water injection development, with the increase of flooding degree, on the one hand, the oil saturation of the oil reservoir continues to decline, the water saturation continues to increase, and the water content continues to rise until the oil reservoir completely produces water; On the other hand, the injected fresh water continuously dissolves the salt in the formation and exchanges ions with the bound water in the oil formation. Although the salinity of injected water increases to a certain extent, the salinity of the mixed liquid formation water in the whole reservoir continues to decline, that is, the formation water is "desalted", and the resistivity of the mixed liquid continues to increase, until the salinity of the mixed formation water is close to the salinity of the injected water, and the whole ion exchange tends to be dynamic equilibrium. Therefore, when fresh water with certain conductivity enters the reservoir at the initial stage of water flooding, the reservoir water saturation increases and the resistivity decreases obviously. When the reservoir water is flooded to a certain extent, due to desalination, the salinity of the mixed formation water decreases, and its influence on the resistivity exceeds that of the increase of water saturation, and the resistivity of the water-flooded reservoir will increase rapidly.

At the initial stage of flooding, due to the local washing, the overall decrease of resistivity is not obvious, and it is relatively difficult to identify the thin layer of about 2m in the initial stage of flooding. However, it can still be qualitatively judged from the logging resistivity morphology. Because of the small washing thickness, different flooding grades can not be divided like the thick layer, but because of the local decrease of resistivity after washing, the peak state of logging resistivity changes in the whole interval. Generally, the resistivity of thin layer logging shows a good centrosymmetric peak state before water flooding, which corresponds well with the SP pattern. After water flooding, due to the decrease of the lower (or upper) resistivity, the peak resistivity deviates from the top or bottom, which is obviously asymmetrical with SP.

1.2 Study on the distribution law of waterlogged layer

The reservoirs in the study area are dominated by strong flooding and relatively strong flooding, and the flooding index is generally distributed in a ring or band with the gas injection well as the low value center (high flooding degree). In the main part of the structure, the microfacies zones such as estuarine bar and underwater distributary channel have good physical properties and high waterlogging degree. The northwest, west, south and southwest of the study area are active, and the flooding degree is higher than other parts. Vertically, the level of flooding index has a certain inheritance, but there are differences in each layer. On the plane, the distribution characteristics of water-flooded layers in each small layer are different[1]. The analysis shows that the well area with high degree of flooding is mainly located in the relatively low structure and the area close to the gas injection well, and the reservoir physical property and connectivity are better. On the contrary, the well area with low degree of flooding is generally located in the high structure and far away from the gas injection well area, and the reservoir physical property and connectivity are slightly poor.

1.3 Interpretation results of waterlogged layer

It is difficult to identify and evaluate waterlogged layers with conventional logging data because of the large number of small layers, large number of sand bodies, thin single layer thickness, diverse sedimentary facies zone types, narrow facies zone, rapid phase transition, fracture development, and many factors affecting and controlling waterlogged degree. Based on the geological characteristics and development status of the oilfield, combined with the logging processing and interpretation results, the evaluation method of entropy weight based on chemical thermodynamics is used to evaluate the flooded layer quantitatively.

2. The distribution of remaining oil was studied by numerical simulation

On the basis of reservoir geological reunderstanding and fine reservoir description, dynamic data and dynamic analysis, reservoir engineering and numerical simulation techniques are used to comprehensively study the macroscopic remaining oil distribution.

The main purposes of the simulation study are: (1) to verify and modify the geological model established by the reservoir description, and to review the geological reserves of the reservoir; (2) Study and determine the distribution of remaining oil in the reservoir[2].

2.1 Production dynamic parameters

Production dynamic parameters mainly include: perforation data, oil and water well production data, pressure monitoring data, production testing and production measures. (1) perforation data: including the perforation date of oil and water Wells, top and bottom perforation depth, perforation layer name, effective thickness, permeability, etc. (2) Oil and water well production data: oil well production, shutdown date, daily oil production, water production data, gas injection date and gas injection volume of gas injection well and transfer well data are prepared in monthly form and form VOL file. In combination with formation coefficient and liquid production profile, the gas injection well is split into single layer according to the data of water intake profile. (3) Pressure monitoring data: individual well static pressure and flow pressure data of reservoir layers over the years. Pressure monitoring methods include liquid level conversion value, annulus pressure measurement value, electronic pressure gauge test value, new well RFT data, etc. (4) Test and measure data: liquid production profile, water absorption profile, acidification and fracturing data. Among them, the water intake profile and liquid production profile data are the most direct reference data to realize the split of the injection volume and reflect the liquid production and gas injection volume of each small layer. (5) Other monitoring data: tracer monitoring, PNN logging and other test data. (6) Oil field layer adjustment is frequent, this simulation is based on the current production well data, and also includes the historical production Wells of each layer in the reservoir.

2.2 Historical fitting results

The accuracy requirement of historical fitting should be consistent with the target requirement of project research, and the reliability of prediction target index must be ensured. Different fitting accuracy standards can be established according to different research problems. The fitting accuracy of the series should be higher than that of a single well, the fitting accuracy of the late historical period should be higher than that of the early and middle period, the fitting accuracy of the production should be higher than that of the pressure, the fitting accuracy of the key well should be higher than that of the general well, and the fitting accuracy of the main layer should be higher than that of the non-main layer[3]. The so-called key well refers to the well whose fitting index data is relatively complete and reliable, production history is relatively long, and can basically reflect the main dynamic laws of the reservoir.

2.2.1 Pressure fitting results

The main pressure fitting indexes are: average formation pressure of reservoir and series, static pressure of single well, among which the average formation pressure of series is an important pressure index. The size and variation trend of formation pressure mainly reflect the variation process of formation energy and injection and production of reservoir. Therefore, the fitting of formation pressure mainly adjusts the compression coefficient, edge water energy, reservoir reserves and injection and production volume during development. Due to the serious formation hole in the reservoir, formation pressure has gradually decreased. In recent years, based on the basic development work and the improvement of well pattern, the formation pressure decline trend has been controlled and the pressure change is stable. Analysis of pressure fitting curve, the effect is not ideal, mainly affected by the pressure test well number, test method, formation selection, and shut-in time and other factors, can not fully reflect the pressure change of different layers, the fitting result has a certain error.

2.2.2 Oil production fitting results

The production fitting index mainly includes: reservoir and series water cut, single well water production, single well production (fixed oil production, fitted water cut) and so on. Among them, reservoir and layer water cut, water cut per well and oil production are important production indexes. It can be seen from the diagram that the oil production of each reservoir calculated by the simulation is well fitted to the overall trend of actual oil production, with high correlation coefficient and small error.

2.2.3 Moisture content fitting results

When fitting the water cut of a single well, the main cause of the change of water cut of a single well should be determined by combining the results of the previous well group dynamic analysis and the effect analysis of measures. The following parameters are mainly adjusted in the reservoir water production fitting model: 1) permeability and conductivity of local directional grid; 2) Phase permeability curve shape and end point value; 3) Initial water saturation at individual well sites. 4) Select different relative permeability curves according to seepage characteristics at different time periods.

3. CO2 huff and puff technology to enhance oil recovery

For the application of CO2 injection and production construction, no one mechanism theory can exist independently, and two or even multiple mechanisms must play a role together, and the effective play of these functions is determined by various factors such as fluid properties, reservoir lithology and development methods. However, one or several factors must play a leading role. Specifically for immiscible flooding, the more important factors are the decrease of crude oil viscosity and the continuous expansion of crude oil volume, and for miscible flooding, whether or not to achieve complete miscibility is the main reason for enhanced oil recovery[4].

CO2 hustling is divided into two processes: swallow and spit. Swallow is to inject CO2 into the reservoir and stew the well, while spit is to open the well for production and finally achieve the purpose of increasing the output of the oil well. The displacement mechanism can be summarized briefly: During the immersion stage, the temperature condition of the formation will promote the rapid vaporization of carbon dioxide gas, of course, a considerable part of it will dissolve into the crude oil. At this time, with the continuous increase of CO2 injection amount, the formation temperature is also rising, and this series of changes also causes the volume of underground crude oil to expand dramatically. The phenomenon reflected in mechanics is the increase of pore pressure, which greatly enhances the flow capacity of crude oil. The study found that when CO2 is fully dissolved in crude oil, the volume of crude oil will expand by 10%~40%, which is a very impressive data. Of course, while expanding the volume of crude oil, it also greatly reduces the viscosity of crude oil. The viscosity reduction effect of carbon dioxide is becoming more and more obvious, and the highest viscosity reduction range can reach about 90%. The lower the viscosity of crude oil, the more significant the extraction effect. Due to the extraction effect, the light components are continuously extracted and stripped, and the viscosity of the residual oil left after huff and puff will continue to increase. There are two very important parameters that have to be explained separately, that is, formation permeability and formation pressure coefficient, because they are important factors affecting the effect of CO2 huff and puff operation. When the values of both are at a low level, the situation of ineffective CO2 injection huff and puff will occur. The formation permeability and pressure coefficient of construction oil well should be greater than a certain value as far as possible. CO2 huff and huff can be applied to a wide range of reservoirs, such as reservoirs with low oil saturation and heavy oil reservoirs with low viscosity. The viscosity threshold is generally 2000mPa • s, and there are remaining oil on the top of most of the inclined oil reservoirs in chunks. Because such reservoirs often have strong heterogeneity, poor connectivity, and can not be connected, there is no way to form an injection-production system in the entire reservoir area. In these cases, through small-scale investment, CO2 throughput can be quickly effective and achieve good results, so it is favored by various oil fields.

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