Study of a quantitative characterization parameter "oil and gas producing efficiency" of the producing degree of reserves in the developed area

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Abstract. Implementing the producing degree of reserves in the developed area is of great significance for timely understanding of oil and gas development trends in the developed area, and then taking targeted adjustment measures to improve oil and gas producing efficiency. On the basis of the analysis of different scale pore percolation capacity of reservoir and the study of four kinds of porosity (connected porosity, effective porosity, flowing porosity, filling porosity) and their corresponding calculation models of oil saturation, a quantitative characterization parameter - "oil and gas producing efficiency" of the producing degree of reserves in the developed area is proposed, and its theoretical discussion and case analysis are carried out. Research shows: 1) Oil and gas producing efficiency is the ratio of the reserves involved in percolation to geological reserves in the developed area of the oilfield, which is finally expressed as the ratio of the product of the flowing porosity and the original oil saturation of the flowing pores to the product of the connected porosity and the original oil saturation of the connected pores. 2) Reservoir flowing porosity and the original oil saturation of flowing pores are a function of displacement power, while the original oil saturation of connected pores is a function of reservoir forming power. Therefore, the oil and gas producing efficiency is essentially a coupling function of displacement power and reservoir forming power. 3) When the displacement power is greater than the reservoir forming power, the oil and gas will be fully developed, and the oil and gas producing efficiency will be 1; when the displacement power is less than the reservoir forming power, the oil and gas will be partially developed, and the oil and gas producing efficiency will be less than 1. 4) The calculation examples of X oilfield in Ordos Basin show that the connected porosity is 11.2%, the original oil saturation of the connected pores is 57.1%, the flowing porosity is 5.32%, the oil and gas producing efficiency is 0.832, and the oil and gas are partially developed. If the oil and gas are to be fully developed, the production pressure difference can be increased from 4.1MPa to 6.2MPa. 5) The study of oil and gas producing efficiency deepens the understanding of reserves producing status in the developed area of the oilfield, and has guiding significance for the targeted production adjustment and production pressure difference optimization of the oilfield.
1. Introduction
In the process of oilfield development, when the reservoir displacement power is fixed, only the part of pore throat network whose pore throat scale is larger than a certain limit usually has seepage, while the other part of pore throat network which is lower than this limit cannot have seepage, that is, the seepage of fluid in the pore throat network has selectivity. This phenomenon can be understood as: with the decrease of pore throat size, the capillary force on the fluid particle and the molecular force on the surrounding solid interface are strengthened, and the seepage resistance is increased. When a certain pore size limit is reached, displacement power and seepage resistance are in equilibrium. When the throat diameter is greater than the pore size limit, the displacement power is greater than the seepage resistance, and the fluid flows. When the throat diameter is less than the pore size limit, the displacement power is less than the seepage resistance, and the fluid does not flow. Therefore, the reservoir fluid in the developed area of the oilfield cannot be fully developed, and the reserves in the developed area are not fully developed. Implementing the producing degree of reserves in the developed area is of great significance for timely understanding of oil and gas development trends in the developed area, and then taking targeted adjustment measures to improve oil and gas producing efficiency.

Reserve producing degree is one of the important indexes of oilfield development, and it is also the main content of dynamic analysis in oilfield development management [1]. For a long time, scholars have carried out a lot of research work and formed some technical methods to determine the reserve producing degree [2-18]. For example, the water injection profile of water injection well and the liquid production profile of oil production well are used to calculate the reserves producing degree in the oilfield [2-7], the dynamic monitoring data of the oilfield and numerical simulation method are used to analyze the reserves producing degree [8-11], the effective driving radius and producing coefficient of the reservoir are used to calculate the reserves producing degree [12-16], and the limit injection production well spacing method is used to calculate the reserves producing degree [17-18]. However, these methods mainly determine the producing degree of oilfield geological reserves, that is, the ratio of the geological reserves in the developed area to the geological reserves that have been put into development [1], and are finally reflected as the product of the plane and vertical sweep coefficient. Therefore, most scholars have researched development plans around increasing the producing degree. The core idea is to expand the developed area and increase the developed thickness [19-22]. On the whole, there are few reports about the reserves producing degree in the developed area at present, and there is no clear understanding of the reserves involved in percolation in the developed area of the oilfield, which is not conducive to the dynamic monitoring and targeted production adjustment of the reserves producing status in the developed area. Therefore, on the basis of the analysis of the percolation capacity of different scales pore of reservoir and the establishment of the calculation model of four kinds of porosity (connected porosity, effective porosity, flowing porosity, filling porosity) and their corresponding oil saturation of reservoir, this paper puts forward a quantitative index - "oil and gas producing efficiency", which represents the producing degree of reserves in the developed area, and makes theoretical discussion and case analysis.

2. Analysis of seepage capacity in different scales pores of reservoir
In the three-dimensional pore throat network of reservoir, most of the pores can always find other pores connected with their matching positions, but there are also a few unconnected pores, and the reservoir fluid seepage occurs in the connected pores. According to the pore size, the connected pores can be divided into three types: hypercapillary pores, capillary pores and microcapillary pores [23]. Among them, hypercapillary pore refers to the millimeter scale pore with an aperture of > 0.5mm, in which the fluid can flow freely under the action of gravity. Capillary pore is a kind of micro pore whose pore diameter is between 0.5mm and 0.2μm, because the pore diameter is small, the fluid particles cannot flow freely under the action of capillary force and molecular force of surrounding solid interface, and can only flow under the action of displacement power. Microcapillary pore is a kind of nanometer pore with pore diameter less than 0.2μm, in this kind of pore, the intermolecular gravity is very large, and the fluid cannot flow freely under the condition of reservoir. Obviously, the percolation of reservoir fluid
mainly occurs in the hypercapillary and capillary pores, while the fluid in the microcapillary pores does not have the theoretical flowability and assumes the adsorption state. Therefore, the connected hypercapillary and capillary pores are the effective pores of theoretical seepage, while the microcapillary pores are the ineffective pores. However, under the actual oilfield production conditions, the fluid in the effective pore is not completely flowable, and its flow mainly depends on the relationship between displacement power and seepage resistance. When the displacement power is greater than the seepage resistance, the fluid can flow. This part of effective pore is flowing pore. When the displacement power is less than the seepage resistance, the fluid cannot flow, and this part of effective pore is non-flowing pore. In addition, in the process of oil and gas accumulation, oil and gas filling is not completely filled with effective pore space, and the degree of filling mainly depends on the relationship between reservoir forming power and seepage resistance. When the reservoir forming power is greater than the seepage resistance, this part of the effective pore filled with oil and gas is the filling pore. When the reservoir forming power is less than the seepage resistance, this part of the effective pore which cannot be filled with oil and gas is the non-filling pore.

To sum up, the connectivity, pore size, theoretical flowability, production flowability and filling flowability of pores in the reservoir are different. However, in general, there are regular corresponding relations and unique seepage characteristics between pores of different scales, which are summarized as table 1.

**Table 1. Characteristics and corresponding relationship of seepage in different scales pores of reservoir**

| classification basis | connectivity | pore size          | theoretical flowability | production flowability | filling flowability |
|-----------------------|--------------|--------------------|-------------------------|------------------------|-------------------|
| total pore            | connected    | hypercapillary pore| effective               | flowing                | filling            |
|                       | unconnected  | microcapillary pore| ineffective             | non-flowing            | non-filling       |
| connected pore        | capillary    |                    |                         |                        |                   |
| unconnected pore      |              |                    |                         |                        |                   |

It can be seen from table 1 that the corresponding relationship between pore spaces of different scales of the reservoir is as follows. ①total pore of reservoir ≥ connected pore ≥ effective pore ≥ flowing pore. ②total pore of reservoir ≥ connected pore ≥ effective pore ≥ filling pore. ③The relative size of flowing pore and filling pore mainly depends on the displacement power and reservoir forming power. If displacement power > reservoir forming power, flowing pore > filling pore. If displacement power < reservoir forming power, flowing pore < filling pore. ④Among them, the effective pore has theoretical flowability, the flowing pore has production flowability, and the filling pore has filling flowability.

3. Calculation model of reservoir porosity and oil saturation

According to the analysis of the seepage capacity of different scale pores in the reservoir, there are four types of pores related to seepage: connected pores, effective pores, flowing pores and filling pores. There are four types of porosity: connected porosity, effective porosity, flowing porosity and filling porosity. There are four kinds of oil saturation corresponding to porosity: connected pore oil saturation, effective pore oil saturation, flowing pore oil saturation and filling pore oil saturation.

3.1. Calculation model of reservoir porosity

In order to illustrate the internal relationship between four kinds of porosity and four kinds of oil saturation, a reservoir porosity model is established (Fig. 1).
Assuming that the rock volume is $V$, the connected pore volume is $V_p$, the effective pore volume is $V_e$, the flowing pore volume is $V_f$, the filling pore volume (or the crude oil volume) is $V_{in}$, the displacement power (or the production pressure difference) is $\Delta p$, and the reservoir forming power (or the filling pressure) is $\Delta p_{in}$. Then the reservoir connected porosity $\varphi_p$, effective porosity $\varphi_e$, flowing porosity $\varphi_f$ and filling porosity $\varphi_{in}$ are respectively:

$$\varphi_p = \frac{V_p}{V} \times 100\%$$  \hspace{1cm} (1)

Formula (1) shows that the connected porosity of reservoir is the ratio of connected pore volume to rock volume, expressed as percentage. The connected porosity of reservoir represents the pore throat network space of fluid mass transfer in reservoir rock. The mass transfer in this paper has two characteristics: one is the percolation mass transfer of fluid in the hypercapillary and capillary pores, the other is the diffusion mass transfer of fluid in the microcapillary pores.

$$\varphi_e = \frac{V_e}{V} \times 100\%$$  \hspace{1cm} (2)

Formula (2) shows that the effective porosity of reservoir is the ratio of effective pore volume to rock volume, expressed as percentage. The effective porosity of the reservoir represents the pore throat network size of the theoretical seepage flow in the reservoir rock.

$$\varphi_f(\Delta p) = \frac{V_f(\Delta p)}{V} \times 100\%$$  \hspace{1cm} (3)

Formula (3) shows that flowing porosity is the ratio of flowing pore volume to rock volume, expressed as a percentage. In the process of oilfield development, with the change of displacement power, the pore throat network space that can start and participate in seepage changes. That is to say, the flowing porosity of reservoir also changes, so the flowing porosity is a function of displacement power. At the same time, the reservoir flowing porosity represents the pore throat network size of fluid production seepage in reservoir rock.

$$\varphi_{in}(\Delta p_{in}) = \frac{V_{in}(\Delta p_{in})}{V} \times 100\%$$  \hspace{1cm} (4)

Formula (4) shows that filling porosity is the ratio of filling pore volume (or crude oil volume) to rock volume, expressed as percentage. During the process of oil and gas filling, the pore throat network space of oil and gas filling changes with the change of reservoir forming power. That is to say, the filling porosity also changes, so the filling porosity is a function of reservoir forming power. At the same time, the reservoir filling porosity represents the pore throat network size of fluid filling and seepage in reservoir rock.

![Figure 1. Pore model of reservoir](image)
3.2. Calculation model of reservoir oil saturation

Correspondingly, the oil saturation corresponding to four kinds of pores (original oil saturation of connected pores $S_{oi-p}$, original oil saturation of effective pores $S_{oi-e}$, original oil saturation of flowing pores $S_{oi-f}$ and original oil saturation of filling pores $S_{oi-in}$) is expressed as follows:

$$S_{oi-p} (\Delta p_{in}) = \frac{V_{in}(\Delta p_{in})}{V_p} \times 100\%$$  \hspace{1cm} (5)

Formula (5) shows that the original oil saturation of connected pore is the ratio of filling pore volume (or crude oil volume) to connected pore volume, expressed in percentage. The original oil saturation of the connected pores is a function of the reservoir forming power because the volume of the filling pore changes with the reservoir forming power.

$$S_{oi-e} (\Delta p_{in}) = \frac{V_{in}(\Delta p_{in})}{V_e} \times 100\%$$  \hspace{1cm} (6)

Formula (6) shows that the original oil saturation of effective pore is the ratio of filling pore volume (or crude oil volume) to the effective pore volume, expressed as a percentage. As the volume of the filling pore changes with the reservoir forming power, the original oil saturation of the effective pore is also a function of the reservoir forming power.

$$\begin{cases} S_{oi-f} = \frac{V_f(\Delta p)}{V_f(\Delta p)} \times 100\% \leq 100\%, \Delta p \geq \Delta p_{in} \\ S_{oi-f} = \frac{V_f(\Delta p)}{V_f(\Delta p)} \times 100\% = 100\%, \Delta p < \Delta p_{in} \end{cases}$$  \hspace{1cm} (7)

Formula (7) shows that the original oil saturation of reservoir flowing pore is a subsection function of displacement power. When the displacement power is equal to or greater than the reservoir forming power, all the oil and gas will be produced. At this time, the original oil saturation of the flowing pore is the ratio of the filling pore volume (or crude oil volume) to the flowing pore volume, and $S_{oi-f} \leq 1$. When displacement power is less than reservoir forming power, oil and gas can only be partially produced. At this time, the original oil saturation of flowing pore is the ratio of flowing pore volume to flowing pore volume, and $S_{oi-f} = 100\%$.

$$S_{oi-in} = \frac{V_{in}(\Delta p_{in})}{V_{in}(\Delta p_{in})} \times 100\% = 100\%$$  \hspace{1cm} (8)

Formula (8) shows that the original oil saturation of the filling pore $S_{oi-in}$ is always 100%.

According to formula (1) - (8), we can get:

$$\begin{cases} \varphi_p \cdot S_{oi-p} = \varphi_e \cdot S_{oi-e} = \varphi_{in} \cdot S_{oi-in} = \varphi_f \cdot S_{oi-f}, \Delta p \geq \Delta p_{in} \\ \varphi_p \cdot S_{oi-p} = \varphi_e \cdot S_{oi-e} = \varphi_{in} \cdot S_{oi-in} > \varphi_f \cdot S_{oi-f}, \Delta p < \Delta p_{in} \end{cases}$$  \hspace{1cm} (9)

Description of formula (9): ① The volume of crude oil in the connected pore, the effective pore and the filling pore are always equal. ② When the displacement power is equal to or greater than the reservoir forming power, all the oil and gas will be produced. At this time, the volume of crude oil in the connected pores of the reservoir is equal to that in the flowing pores of the reservoir. ③ When the displacement power is less than the reservoir forming power, the oil and gas will be partially produced, and the volume of crude oil in the connected pores of the reservoir is greater than that in the flowing pores of the reservoir ($S_{oi-f} = 100\%$).

4. Reservoir oil and gas producing efficiency

4.1. Connotation of oil and gas producing efficiency

On the basis of the analysis of different scale pore percolation capacity and pore model of reservoir, four kinds of porosity (connected porosity, effective porosity, flowing porosity, filling porosity) of reservoir and the corresponding calculation model of oil saturation, in order to quantitatively characterize the
reserves producing degree in the developed area, a quantitative index "oil and gas producing efficiency" is proposed. Oil and gas producing efficiency actually refers to the ratio of reserves involved in percolation in the developed area of the oilfield to geological reserves in the developed area. According to this definition, if the oil-bearing area of oil field is $A_1$ and the effective thickness is $h_1$, the pore throat sweep coefficient can be expressed as:

$$\omega = \frac{V_f S_{oi-f}}{V_{in}} = \frac{A_1 h_1 \phi_f S_{oi-f}}{A_1 h_1 \phi_f S_{oi-p}} = \frac{\phi_f S_{oi-f}}{\phi_f S_{oi-p}}$$  \hspace{1cm} (10)$$

Formula (10) shows that the oil and gas producing efficiency $\omega$ is finally expressed as the ratio of the product of flowing porosity and original oil saturation of flowing pores to the product of connected porosity and original oil saturation of connected pores. Because the flowing porosity $\phi_f$ is a function of displacement power, the original oil saturation of flowing pore $S_{oi-f}$ is a subsection function of displacement function, and the original oil saturation of connected pore $S_{oi-p}$ is a function of reservoir forming power, the oil and gas producing efficiency of reservoir is essentially a coupling function of displacement power and reservoir forming power.

Substituting formula (9) into formula (10), and taking into account formula (7), we can get:

$$\left\{ \begin{array}{l} \omega = \frac{V_f S_{oi-f}}{V_{in}} = 1, \Delta p \geq \Delta p_{in} \\ \omega = \frac{V_f S_{oi-f}}{V_{in}} = \frac{A_1 h_1 \phi_f S_{oi-f}}{A_1 h_1 \phi_f S_{oi-p}} = \frac{\phi_f}{\phi_f S_{oi-p}}, \Delta p < \Delta p_{in} \end{array} \right.$$  \hspace{1cm} (11)$$

Formula (11) shows that when the displacement power is equal to or greater than the reservoir forming power, the reservoir oil and gas producing efficiency is equal to 1, and all oil and gas are produced. When displacement power is less than reservoir forming power, reservoir oil and gas producing efficiency is less than 1, and oil and gas are partially produced.

### 4.2 Determination method of oil and gas producing efficiency

When the displacement power of the developed area is equal to or greater than the reservoir forming power, the reservoir oil and gas producing efficiency is equal to 1. Therefore, this paper only discusses the determination method of reservoir oil and gas producing efficiency when displacement power is less than reservoir forming power.

According to formula (11), when the displacement power is less than the reservoir forming power, three parameters are needed to determine the calculation of the reservoir oil and gas producing efficiency in the developed area of the oilfield: the connected porosity $\phi_p$, the original oil saturation of the connected pore $S_{oi-p}$ and the flowing porosity $\phi_f$. In addition, considering the coupling effect of displacement power $\Delta p$ and reservoir forming power $\Delta p_{in}$, five parameters need to be determined.

1. **Displacement power $\Delta p$**: Determined according to the production performance data of the oilfield.

2. **Connected porosity $\phi_p$ and original oil saturation of connected pore $S_{oi-p}$**: They can be determined directly in the laboratory or by logging interpretation.\(^1\) Laboratory direct determination: Because of the duality of the mass transfer of the connected pore fluid, it is impossible for the liquid to enter the microcapillary pores, so the conventional laboratory liquid saturation method cannot measure the connected porosity. Relatively speaking, the gas can enter into the microcapillary pores of rock to a certain extent, and the connected porosity can be roughly determined by the gas method. The original oil saturation measured by the corresponding laboratory should be the original oil saturation of connected pores. However, when the experimental gas is nitrogen or helium, the molecular weight of helium is lower and it can enter into smaller pores than nitrogen [24]. Therefore, helium is more accurate than nitrogen in the determination of connected porosity. This shows that the connected porosity measured by different experimental gases is different. Therefore, how to accurately determine the connected porosity by experimental means is still a direction to be worked on.\(^2\) Log interpretation: As the porosity of gas measurement is connected porosity, the original oil saturation measured in laboratory is original oil saturation of connected pores. Therefore, the porosity or original oil saturation obtained
by core calibration logging method should also be connected porosity or original oil saturation of connected pores.

(3) Reservoir forming power \( \Delta p_{\text{nc}} \): After oil and gas enter the reservoir from source rock, great changes have taken place due to pore structure, fluid properties and temperature and pressure environment conditions. For example, pore size and porosity increase, formation pressure decrease, temperature and salinity decrease and so on. At this time, oil and gas filling pressure is mainly oil column buoyancy. When the height of the oil column is higher and the filling pressure is higher, the oil saturation of the corresponding reservoir is higher. On the contrary, the smaller the height of the oil column and the lower the filling pressure, the smaller the corresponding oil saturation. It can be seen that there is a one-to-one relationship between filling pressure and oil saturation. Therefore, according to the original oil saturation of connected pores, the reservoir forming power can be determined. The main ideas are as follows:①Firstly, the curve of constant pressure mercury injection is obtained by the method of constant pressure mercury injection.②Secondly, read the mercury pressure corresponding to the original oil saturation of the connected pores on the curve of constant pressure and mercury injection, which is the reservoir forming power.

(4) Flowing porosity \( \phi_f \): Flowing porosity is a function of displacement power, which can be used to determine flowing porosity. The main ideas are as follows:①Firstly, the curve of constant pressure mercury injection is obtained by the method of constant pressure mercury injection.②Secondly, read the porosity corresponding to displacement power on the curve of constant pressure and mercury injection, that is, flowing porosity.

5. Calculation example of oil and gas producing efficiency
The X oilfield in Ordos Basin is located in Qingyang City, Gansu Province, in the southwest of the Northern Shaanxi Slope, with an area of about 5000km² and proved geological oil reserves of 23967 × 10⁴t. The main oil-bearing formation of X oilfield is sand group C₈₁ of Yanchang Formation of Upper Triassic of Mesozoic, which is mainly composed of front subfacies in delta sedimentary system. It is interbedded with light grey, grey green medium thick medium fine sandstone, dark grey mudstone and sandy mudstone, with an average thickness of 40.9m. The original formation pressure of the oil layer is 17MPa. After more than 10 years of development, the current formation pressure of the oilfield is 13.5MPa, the average bottom hole flow pressure is 9.4MPa, and the average production pressure difference is 4.1MPa.

5.1. Connected porosity and original oil saturation of connected pore
The well logging interpretation method is used to determine the connected porosity and the original oil saturation of the connected pore. According to the log interpretation data, the characteristics of connected porosity, permeability and original oil saturation of connected pore in C₈₁ reservoir of X oilfield are statistically analyzed (Fig.2~Fig.4). It can be seen from Fig.2 that the connected porosity of the reservoir is distributed between 6% and 16%, with an average porosity of 11.2%. It can be seen from Fig.3 that the reservoir permeability is distributed between 0.01 and 4.8 × 10⁻³ μm², with an average permeability of 0.84 × 10⁻³ μm². It can be seen from Fig.4 that the original oil saturation of the connected pores of the reservoir is between 40% and 85%, with an average oil saturation of 57.1%. In conclusion, C₈₁ reservoir in X oilfield has the characteristics of low porosity, low permeability and low oil saturation.
5.2. Reservoir forming power
First, the average constant pressure mercury injection test curve of C81 reservoir in X oilfield is obtained (Fig.5). Since the average original oil saturation of the connected pores of C81 reservoir in the X oilfield is 57.1%, point B with a mercury saturation of 57.1% on the constant pressure mercury injection curve is the point of reservoir forming power. It can be seen from Fig.5 that the average reservoir forming power of X oilfield is 91MPa (experimental test pressure). The interfacial tension between oil and water is 25mN/m and the wetting angle is 0° under formation conditions. The surface tension of mercury is 480mN/m and the wetting angle of mercury is 140° under laboratory conditions (Table 2). According to the conversion of the Young-Laplace equation, the average reservoir forming power under formation conditions is 6.2 MPa.

Figure 5. Average constant pressure mercury injection curve of C81 reservoir in X oilfield
Table 2. Wetting angle and interfacial tension in different systems

| condition      | fluid system | wetting angle θ (°) | interfacial tension σ (mN/m) |
|----------------|--------------|---------------------|-----------------------------|
| laboratory     | air-mercury  | 140                 | 480                         |
| formation      | oil-water    | 0                   | 25                          |

5.3. Flowing porosity

The flowing porosity can be determined by the constant pressure mercury injection curve combined with the average production pressure difference. It is known that the average production pressure difference of C81 reservoir in X oilfield is 4.1 MPa, so point A is the displacement power point (Fig.5). It is assumed that the reservoir connected porosity is ϕp, the production pressure difference is Δp, the reservoir flowing porosity is ϕf(Δp), and the mercury saturation corresponding to the flowing porosity is $S_{Hg-f}(Δp)$. Then the flowing porosity of point A can be calculated by the following formula:

$$ϕ_f(Δp) = ϕ_p \cdot S_{Hg-f}(Δp)$$  \hspace{1cm} (12)

For example, the average production pressure difference of C81 reservoir in X oilfield is 4.1 MPa. The interfacial tension between oil and water is 25mN/m and the wetting angle is 0° under formation conditions. The surface tension of mercury is 480mN/m and the wetting angle of mercury is 140° under laboratory conditions (Table 2). The Young-Laplace equation can be used to convert oilfield production pressure difference to laboratory test pressures. The calculation shows that the production pressure difference of 4.1MPa is equivalent to the test pressure of 60.3 MPa. As can be seen from Fig.5, the mercury saturation $S_{Hg-f}(4.1MPa)$ corresponding to this production pressure difference is 47.5%. It is also known that the average connected porosity of the reservoir is 11.2%, so according to formula (12), the flowing porosity of the reservoir at point A is $ϕ_f(4.1MPa)=11.2%\times47.5%\approx5.32\%$.

5.4. Reservoir oil and gas producing efficiency

The displacement power (4.1 MPa) of C81 reservoir in X oilfield is less than that of reservoir forming power (6.2 MPa), and the average connected porosity is 11.2%, the average original oil saturation of connected pore is 57.1%, and the average flowing porosity is 5.32%. According to formula (11), the oil and gas producing efficiency is $ω = \frac{ϕ_f}{ϕ_{oil}} = \frac{5.32\%}{11.2\%\times57.1\%} \approx 0.832$. Obviously, oil and gas in C81 reservoir of X oilfield are only partially produced under the displacement power of 4.1 MPa. In order to improve oil and gas producing efficiency, the production pressure difference can be increased from 4.1MPa to 6.2MPa. That is, adjust the displacement power point A to the filling power point B.

It should be noted that the above example determines the average oil and gas producing efficiency of X oilfield. Due to the different reservoir forming power and displacement power in different parts of the oilfield, the oil and gas producing efficiency of different well areas or different wells must be different in the production process of the oilfield. Therefore, the dynamic monitoring of oil and gas producing efficiency in specific well area or well and the coordination of the coupling relationship between displacement power and reservoir forming power are of more guiding significance for the targeted production adjustment and production pressure difference optimization of the oilfield.

6. Conclusion

(1) This paper puts forward a quantitative index - "oil and gas producing efficiency", which is used to describe the reserves producing degree in the developed area. Oil and gas producing efficiency refers to the ratio of the reserves involved in percolation in the developed area of the oilfield to the geological reserves in the developed area, which is finally expressed as the ratio of the product of the flowing porosity and the original oil saturation of the flowing pores to the product of the connected porosity and the original oil saturation of the connected pores of the reservoir. In essence, oil and gas producing efficiency is a coupling function of displacement power and reservoir forming power. When the displacement power is greater than the reservoir forming power, the oil and gas will be fully produced,
and the reservoir oil and gas producing efficiency is 1. When the displacement power is less than the reservoir forming power, the oil and gas will be partially produced, and the reservoir oil and gas producing efficiency will be less than 1.

(2) Different parts of the oilfield have different reservoir forming power and displacement power, and the oil and gas producing efficiency of different well areas or different wells is also different in the production process of the oilfield. Therefore, the dynamic monitoring of oil and gas producing efficiency in specific well area or well and the coordination of the coupling relationship between displacement power and reservoir forming power are of more guiding significance for the targeted production adjustment and production pressure difference optimization of the oilfield.

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