Identification of Flow Channels using Streamline Numerical Simulation and Fuzzy Comprehensive Evaluation

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Abstract. Analyzing the flow channels between production wells and injection wells is very important to develop an oil field. For the oilfield D, the streamline numerical simulation method is adopted to output the flow line distribution, the allocation factor graph of injection wells, and water injection efficiency graph between two wells. At the end, the fuzzy comprehensive evaluation technique is also used to verify the results in the oilfield.

Introduction

The traditional methods of identifying the advantaged flow field include geology analysis, log interpretation, dynamic analysis, isotope tracer method, and so on. The authors take streamline-based flow simulation method and fuzzy comprehensive evaluation to identify the distribution of 3D flow field between the oil wells and the water wells in D Oilfield. Identifying the advantaged flow field by fuzzy comprehensive evaluation method is to consider the comprehensive impact by a variety of factors [1]. We choose the appropriate fuzzy transformation membership function to transform each non-linear factor into linear relationship factors which is related to advantaged flow field. Then we transform these factors by next step fuzzy transformation until the end of the fuzzy transformation.

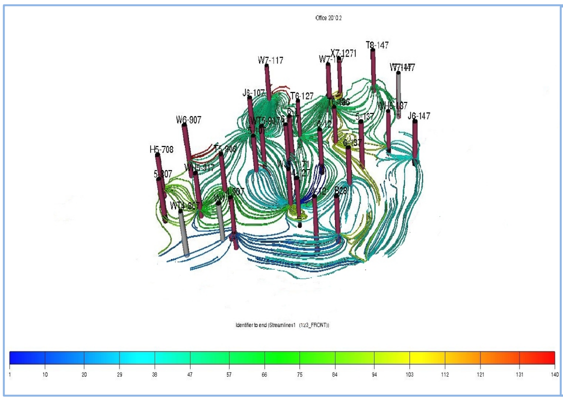
Analyzing the advantaged flow field by the Streamline numerical simulation

Analysis the advantaged flow field by the Three-dimensional Streamline FIG

It can be seen from the 3D visualization of the streamline shown in Figure 1, the streamline is thick between the injection well of WT4-807 and the production well of 4-907 in VII9 layer. The same situation occurred between WJ4-107 injection well and 4-12, 5-127 Production well. So we can make the conclusion that most of injected water flows into the production wells along the advantaged flow field direction and finally leads to the invalid water flow channel.

Study the advantaged flow field by the injection well factor chart

The distribution file that output by the results of streamline simulation provides the yield of water that distribute to each effective oil well. So we get the water injection assignment Table1 of WT4-807 and J4-107 wells and draw the distribution factor Chart 3. What can be seen from the distribution factor figure is that there is advantaged flow field between the injection well WT4-807 and the production well 4-907, so we can analyze the advantaged flow field in VII9 layer by the injection well factor chart combined with streamline distribution diagram.



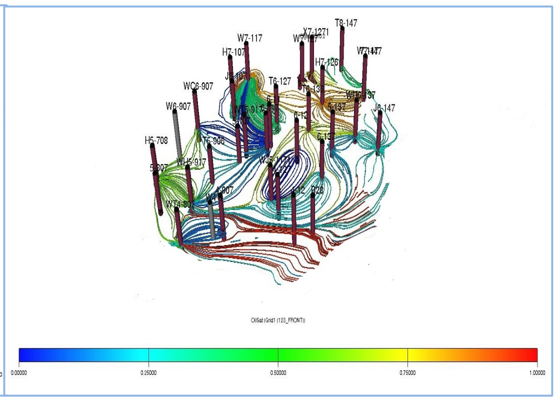


Fig. 1 Streamline distribution（YEAR:2001） Figure 2 Streamline distribution（YEAR:2015）

Table 1 water injection factor table of WT4-807 and WJ4-107

Water injection well	Effective well	Distribution of water injection quantity [m^3]	Distribution factor
WT4-807	4-907	39.3	0.5
WT4-807	T4-507	12.4	0.2
WT4-807	H3-507	5.8	0.05
WT4-807	5-137	8.9	0.08
WT4-807	6-11	7.1	0.06
WT4-807	J6-147	6.1	0.07
WT4-807	H5-708	5.1	0.04
WJ4-107	H7-176	13.7	0.12
WJ4-107	3-127	12.5	0.25
WJ4-107	6-12	11.3	0.33
WJ4-107	H3-167	24.3	0.1
WJ4-107	B28	11.2	0.2

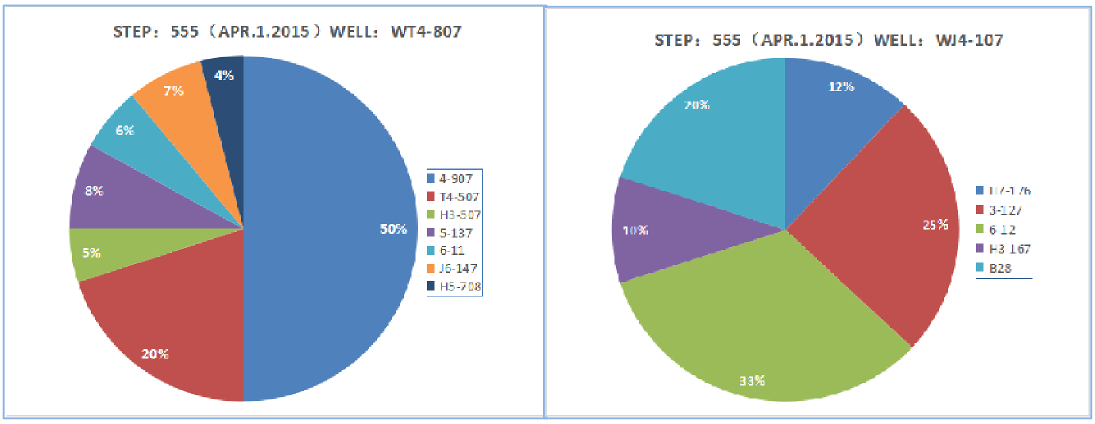


Fig.2 The distribution factor chart of WT4-807 and WJ4-107

Determination of the advantaged flow field by water injection efficiency chart

The water injection efficiency of each injection well is calculated by streamline numerical simulation [2]. The daily injection quantity of each injection well is defined as the X coordinate [3-4], The daily oil production of every production well related to the injection well is taken as Y coordinate. We define the futile cycle injection wells as water injection efficiency is less than 50%. I found only two wells' water efficiency (WH5-137 and WF8-19) is greater than 50% by calculating 32 injection wells efficiency on the region. The efficiency of other 30 injection wells is all lower than 25%. It shows that these water injection wells have advantaged flow channel in some direction to a production well. The Water injection efficiency chart is shown as Fig 3.

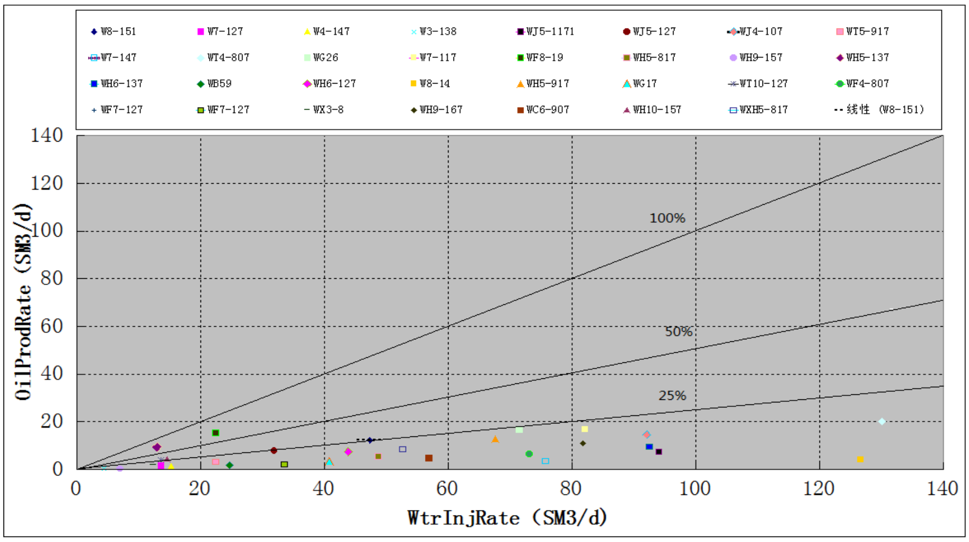


Fig. 3 Injection wells' efficiency of D oilfield VII strata

Determining the advantaged flow field by fuzzy comprehensive evaluation

The WT4-807 well group is selected as an example to study the flow channels by fuzzy comprehensive evaluation. Fuzzy comprehensive evaluation procedure is as follows.

(1) Dynamic and static parameters of Well group WT4-807 is shown in Table 2 and 3.

Table 2 The parameter of WT4-807 wells

Number of well	Permeability [$\times10^{-3}\mu m^2$]	Porosity [%]	Small thickness [m]	Water injection pressure [MPa]	Daily water injection [m^3]	Water injection intensity [$10^4m^3/m$]
WT4-807	120	20	34	20.7	21.42	0.63

Table 3 The parameter of 4-907wells

Number of well	Permeability [$\times10^{-3}\mu m^2$]	Small thickness [m]	Water cut [%]	Daily liquid rate [m^3/d]
4-907	164	45.8	92.7	214.2

(2) Selecting the membership function of wells

It is found that the indicators obey normal distribution by inductive analysis of actual data of the major strata of D oil field VII strata, so I select the normal distribution function as membership function. The normal distribution function is shown in Equation 1:

$$u_y(x) = e^{-[(x-a)/b]^2} \tag{1}$$

where x : evaluation factor, y : comment grade, a, b : index.

(3) Determination of the fuzzy comprehensive judgment matrix above two wells

The fuzzy relationship matrix of well group WT4-807 is obtained by taking the dynamic and static parameters of injection well WT4-807 and production well 4-907 into above membership Eq1. respectively. The matrix for the injection is listed in R1 and R2 as an example.

$$\mathbf{R_1}=\begin{array}{cl}\begin{bmatrix} 0.000243351 & 0.885196987 & 6.13638E-06 \\ 0.681877851 & 6.32076E-15 & 2.60445E-17 \\ 0.629977385 & 6.32076E-15 & 2.60445E-17 \end{bmatrix} & \begin{array}{l}\text{permeability}\\ \text{layer thickness}\\ \text{Porosity}\end{array}\end{array}$$

Invalid circulation low efficiency circulation normal production

$$\mathbf{R_2}=\begin{array}{cl}\begin{bmatrix} 0.007166975 & 0.227492798 & 0.630776927 \\ 0.166173196 & 0.814547105 & 0.080122957 \\ 0.192263306 & 0.611512509 & 0.341622283 \end{bmatrix} & \begin{array}{l}\text{injection pressure}\\ \text{water injection rate}\\ \text{cumulative water injection}\end{array}\end{array}$$

(4)Determination of the weight of static and dynamic parameters of WT4-807 well group

I give dynamic and static factor index weight composition weight Table of WT4-807 well and 4-907 well by related Expert's advice and analytic hierarchy process and the weight composition weight as table 4 and 5 [5].

Table 4 The injection and production well parameters

		Injection well	Production well
Static factors	0.35	permeability: 0.35	The permeability of well: 0.6 Effective thickness: 0.4
		Effective thickness: 0.3	
		Porosity: 0.35	Liquid production rate: 0.5
Dynamic factors	0.65	injection pressure: 0.2	Water cut: 0.5 The permeability of well: 0.6
		water injection rate: 0.4	
		Cumulative water injection: 0.4	Effective thickness: 0.4

(5) Variety of factors fuzzy transformation to determine the advantaged flow field

By multiplying the fuzzy relation matrix and the weight matrix one can get the fuzzy evaluation results of injection well WT4-807 and production well 4-907 (B1, B2), where B1 = (0.23, 0.503, 0.19), B2 = (0.27, 0.23, 0.21). One can get the conclusion that the well WT4-807 is invalid injection well and the well 4-907 is invalid production well.

Conclusions

(1) One can judge the flow channels by combining the streamline numerical simulation method and fuzzy comprehensive evaluation. The former gives the 3D streamline distribution in each layer, allocation factor between injection and production wells so that the flow channels can be identified.

(2) Both methods give similar results. However, the streamline numerical simulation is more intuitive and it can provide very meaningful guidance to exploit the remaining oil.

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