



Re-Fracturing Wells Selection by Fuzzy Comprehensive Evaluation Based on Analytic Hierarchy Process—Taking Mahu Oilfield as An Example

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Re-fracturing treatments of horizontal wells are increasingly gaining popularity to address the issue of rapid production decline and low recovery ratio for the conglomerate reservoir of the Mahu Oilfield. How to effectively select the horizontal wells with potentiality for re-fracturing and conduct the re-fracturing operation to achieve the purpose is the key problem that needs to be investigated urgently. However, the conventional methods for vertical wells are not in our consideration, and some methods for horizontal wells have their limits for the Mahu reservoir. To cope with problems mentioned above, fourteen factors from geology parameters, engineering parameters, and production performance parameters are considered to establish a multi-level evaluation model to quantify the potentiality of each horizontal well for re-fracturing in the Mahu Oilfield. First, the analytic hierarchy process (AHP) is used to obtain the weights of various factors affecting the productivity of horizontal wells, and on this basis, the subordination degree and evaluation matrix are then calculated, and finally, the fuzzy synthetic determination is obtained to determine the candidate wells for re-fracturing. The results have shown that the weights corresponding to engineering parameters obtained by the AHP method are the largest, followed by geology parameters, and the weights of production performance parameters are the minimal relatively; the number of fractures and the sand quantity of single cluster are the main controlling factors in engineering factors, and the initial formation pressure is the main controlling factor in geological factors; there is obvious correlation between the cumulative oil production after 90 days of primary fracturing with final cumulative production. Wells M15, M13, and M7 rank top three among the candidate wells. Through re-fracturing treatment by temporary plugging, the daily oil production of well M15 has increased significantly and is even higher than that of the primary hydraulic fracturing stimulation, confirming the reliability of the proposed selection method.

Keywords: conglomerate reservoir, well selection, re-fracturing, analytic hierarchy process, fuzzy comprehensive evaluation

INTRODUCTION

The conglomerate reservoir of the Mahu Oilfield located in Xinjiang, Northwest China, with low permeability, large two-dimensional stress difference, and strong pressure-sensitive effect, is the largest uncompartimentalized conglomerate reservoir around the world. The factors influencing productivity are complicated and, hence, make the development of the oilfield difficult. Due to the influence of sedimentation, diagenesis, and structure, the conglomerate reservoir in Mahu has the characteristics of small pore throat and extremely poor physical properties. Without hydraulic fracturing, natural industrial productivity cannot be achieved (Jia et al., 2012; Zhao et al., 2016; Zou et al., 2017). Although multi-fractured technology of horizontal wells has been gradually introduced since 2012 in the Mahu Oilfield to improve oil productivity, some severe problems, including rapid production decline and low recovery ratio, usually occur. On the basis of a previous study in the literature (Hu et al., 2004; Yang et al., 2016; Guang and Wang, 2019), re-fracturing is a good treatment to improve oil production and recovery ratio by enlarging the contact area between the wellbore and reservoir. The core problem becomes how to select the horizontal wells with the potentiality for re-fracturing.

Conventional well selection methods such as the empirical method (Gu et al., 2006; Roussel and Sharma, 2013), grey correlation method (Sun et al., 2012; Wen et al., 2015; Zhu et al., 2017; Hui, 2019), and multiple regression method (Liu et al., 2018) have their limitations. The conventional empirical method usually defines a set of criteria, and the well which meets one of them will be regarded as a good candidate well for re-fracturing. It is indeed a valuable tool for vertical wells which have only one hydraulic fracture. For example, Roussel proposed (Roussel and Sharma, 2013) that two groups of wells showed the most promise for re-fracturing: 1) ineffective initial completions with a small initial production decline and 2) long initial fractures in underdepleted reservoirs. Therefore, for horizontal wells with different length of multistage fractures, the empirical method is no longer applicable. As for grey correlation, it is a mathematical statistical method to determine the main controlling factors which will be used for selecting wells. For example, permeability is a controlling factor with the largest correlation degree for a well block, and when selecting candidates, priority is usually given to the wells with high permeability (Hui, 2019). The idea behind the multiple regression method is to regress the relationship between geology and engineering factors with production to predict the re-fracturing effect. The well that can improve productivity after re-fracturing predicted by the regression model will be the potential candidate. However, this method is usually used for vertical wells and also cannot consider the heterogeneity. For the Mahu Oilfield, the reservoir heterogeneity has to be considered, and the predictive production is less accurate than numerical simulation.

There are many factors influencing oil production of horizontal wells, among which the nonlinear relation is strong; however, the impact of various factors on production capacity is

uncertain, which brings great difficulties to select re-fracturing wells. Existing selecting methods of horizontal wells for re-fracturing can be summarized as the fuzzy mathematics method (Tao et al., 2018; Guo et al., 2019), artificial intelligence method (Wu et al., 2001; Zeng et al., 2017), and coefficient introduction method (Lu, 2014; Cui et al., 2018), among which the fuzzy mathematics method is widely used. The fuzzy mathematics method includes fuzzy clustering and fuzzy evaluation.

As mentioned above, the nonlinear relation between influence factors and production is strong, and the artificial intelligence method can solve this problem by using nonlinear activation functions on an artificial intelligence network rather than the mathematical formula. However, a large number of wells are required to improve accuracy when using the artificial intelligence method, which limits its applicability. As for the coefficient introduction method, some evaluation coefficients are introduced by dimensionless treatment. Multiple basic factors are considered to establish a coefficient. For instance, the porous elastic stress steering coefficient (Cui et al., 2018) is introduced by considering the maximum horizontal principal stress, minimum horizontal principal stress, formation pressure, and bottom-hole flowing pressure. The wells with larger or smaller coefficient than the standard value will be eliminated, and the remaining will be proceeded to the screening of next coefficient. The number of candidate wells gradually decreases after layer-by-layer screening. The last remaining wells will be re-fractured. However, it could be possible that some wells eliminated by the first coefficient are suitable to be re-fractured for meeting the standard value of the subsequent coefficients.

The fuzzy clustering method quantifies the potentiality for re-fracturing by establishing an ideal well and then calculating the similarity between each horizontal well and the ideal well. Each parameter of the ideal horizontal well including geology and engineering parameters is taken from the optimal value of candidate well samples. For example, the larger the oil saturation is, the more potentiality the well has for re-fracturing, and the oil saturation of the ideal well will be the maximum value among the values of all candidate wells. On the contrary, the smaller the rate in primary fracturing is, the more potentiality the well has for re-fracturing because the scale of primary fractures is small. Then, the rate of the ideal well will be the minimum value among the values of all candidate wells. The ideal well will be the most suitable to be re-fractured under any condition. Also, the candidate well which is most similar to the ideal well will be the most suitable one. However, the fuzzy clustering method does not consider the weight of each main control factor, which will have a certain impact on the well selection results.

The fuzzy evaluation model considers the weights of control factors by multiplying the parameter matrix and weight matrix, and on this basis, the potentiality of each candidate well can be quantified.

The weight of each control factor is usually obtained by using the mathematical statistical method and analytic hierarchy process (AHP). The AHP is a method for determining weights and analyzing complex decisions. The basic principle of the AHP

is to regard the complex problem as a large system and draw the ordering layers through the analysis of multiple factors. Then, experts are invited to make more objective judgments on the factors at each layer and give a quantitative expression of relative importance accordingly. A mathematical model is established to calculate the weights of factors at each layer and rank them. The AHP method is widely used to calculate weights. Yu et al. determined the main controlling factors using the AHP in a high-water cut oilfield (Yu et al., 2018). Zhang et al. selected wells for acidizing based on the weights obtained by the AHP method (Zhang et al., 2019). Li et al. integrated the AHP, grey correlation, and random forest to determine weights in a tight oil reservoir (Li et al., 2021). Besides, the AHP method is also used to evaluate reservoirs (Lu et al., 2021; Zhang et al., 2021).

The parameter matrix needs to be normalized due to the unit difference. The normalization method will be different based on the influence of parameters to production, such as maximization normalization and minimization normalization.

The fuzzy evaluation method has the advantages of strong systematicness, clear calculation results, and improved algorithm flexibility and intelligence (Wang et al., 2008; Xu, 2011; Hou et al., 2014).

However, the factors considered when using the fuzzy evaluation model generally only include geology and engineering parameters, and the number of sub-factors is small. In this article, the production performance data after primary fracturing including flowback rate and initial production are considered innovatively. For the Mahu conglomerate reservoir with strong heterogeneity, some parameters, e.g., wettability and capillary pressure, are difficult to obtain. The flowback rate after primary fracturing reflects these properties to some degree. Besides, for the multi-fracturing horizontal wells in a tight reservoir, the number of primary fracturing segments and clusters should also be considered when evaluating the potentiality for re-fracturing. To assess the re-fracturing potentiality quantitatively of candidate wells in Mahu block, by considering as many as 14 factors in three categories of geology, engineering, and production performance parameters, we propose a comprehensive fuzzy evaluation mathematical model, which provides an easy-to-use tool to select the re-fracturing wells.

ANALYTIC HIERARCHY PROCESS

The analytic hierarchy process (AHP) is used to determine the weight of each factor. In this study, fourteen factors from geology, engineering, and production performance are considered. The geology factors include initial formation pressure, oil saturation, permeability, porosity, and reservoir thickness. Initial formation pressure represents the energy basis of the reservoir. Oil saturation is the ratio of oil volume to effective pore volume, expressed as a percentage. Permeability refers to the ability of rock that allows fluid to pass through under a certain pressure difference. It is a parameter characterizing the ability of rock to conduct liquid. Porosity is the ratio of the sum of all pore space volumes in rock to the volume of the rock, expressed as a percentage. It is worth noting that reservoir thickness is the horizontal thickness which is the same as the length

of the horizontal well section drilled in the reservoir, not the vertical formation thickness. As for the production performance factors, flowback rate and cumulative oil production after 90 days of primary fracturing are considered. Flowback rate is the ratio of flowback fluid volume to the total pumped fluid volume. Cumulative oil production is the total oil production at some point in time. In this paper, the flowback rate and cumulative oil production after 90 days of primary fracturing are used to reflect some unknown properties which are difficult to obtain, such as wettability and capillary pressure. The engineering factors include the number of fracturing segments, the number of clusters, rate, sand quantity of each cluster, sand ratio, liquid volume of each cluster, and length of the horizontal portion. The number of fracturing segments is also described as the number of stages. The part between the two bridge plugs is one stage. The number of clusters can be explained as the number of fractures. Rate refers to the volume of liquid pumped per minute. Sand quantity of each cluster is the average proppant volume per fracture. Sand ratio is the average ratio of total sand to total fluid per stage. Liquid volume of each cluster is average fluid volume per fracture. Length of the horizontal portion is the total length of the horizontal well section which is different from reservoir thickness.

The hierarchical structure model is established including a target layer and two criterion layers. As shown in **Figure 1**, the target layer is well selection for re-fracturing, criterion layer 1 includes geology, production performance, and engineering set, and criterion layer 2 includes three sets of factors, reflecting their impacts on well selection for re-fracturing.

Judgment Matrix

The judgment matrix is obtained by comparing factors in pairs in one same layer including criterion layer 1 and 2. The element of judgment matrix is indicated as P_{ij} , which means the importance comparison results of the i -th factor and the j -th factor in one same layer. The importance between two elements is determined by the nine-scale method (Ye, 2010) which is shown in **Table 1**. In addition, the judgment matrix has the following properties:

$$P_{ij} = \frac{1}{P_{ji}}. \quad (1)$$

The maximum eigenvalue and weight matrix are calculated by the square root method. First, the product of each row element of the judgment matrix is calculated by

$$M_i = \prod_{j=1}^n P_{ij}, \quad (2)$$

where P_{ij} is the element of the judgment matrix and M_i is the continuous product of elements in each row.

The n -th root of M_i is

$$W_i = \sqrt[n]{M_i}, \quad (i = 1, 2, \dots, n). \quad (3)$$

The weight vector can be obtained by normalizing the n -th root.

$$\omega_i = W_i / \sum_{j=1}^n W_j. \quad (4)$$

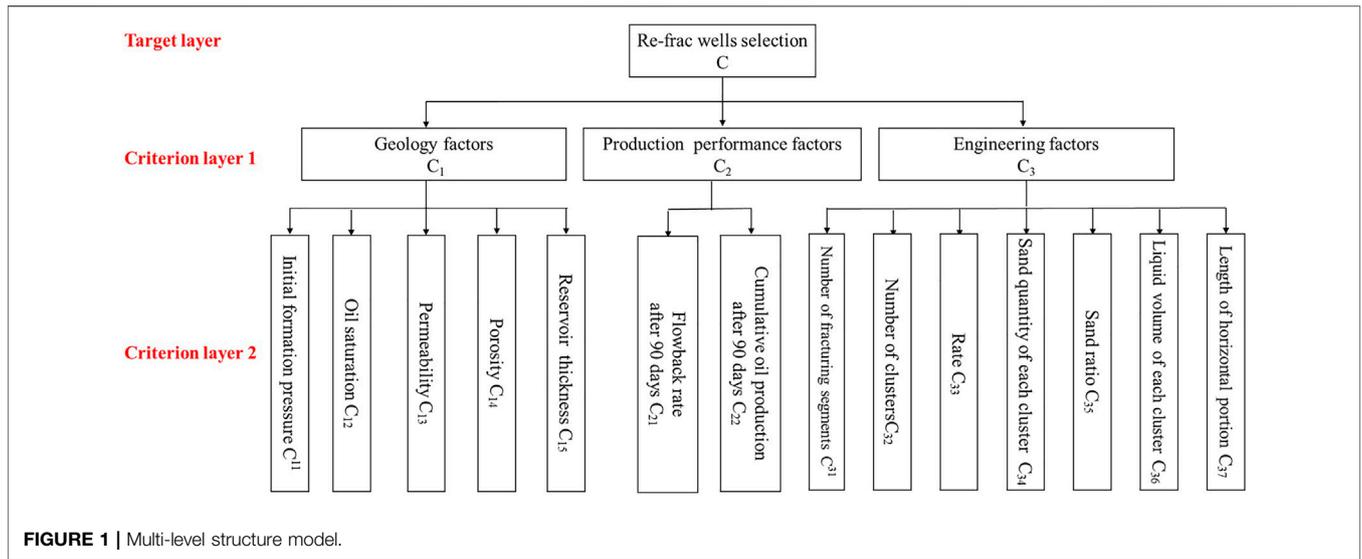


TABLE 1 | Nine-scale evaluation table and its meaning.

Scale value	Meaning
$P_{ij} = 1$	i is as same important as j
$P_{ij} = 3$	i is slightly more important than j
$P_{ij} = 5$	i is obviously more important than j
$P_{ij} = 7$	i is much more important than j
$P_{ij} = 9$	i is extremely important than j
$P_{ij} = 2, 4, 6, 8$	Mid-value judgment of the importance comparison

Finally, the maximum eigenvalue is

$$\lambda_{\max} = \sum_{i=1}^n \frac{(P\omega)_i}{n\omega_i} \tag{5}$$

The expert scoring method is used to judge the importance, and then, the reliability of score-giving will be verified by the consistency test. For the Mahu Oilfield, the experts think that the influence of geology factors is slightly more important than production performance, and the ratio of C_1 to C_2 is 3; in other words, the ratio of C_2 to C_1 is 1/3. Compared to the geology factors, the importance of engineering factors is the mid-value of “same important” and “slightly more important,” and the ratio of C_1 to C_3 is 0.5. The engineering factors are obviously more important than production performance, and the ratio of C_3 to C_2 is 5.

The judgment matrix of criterion layer 1 is

$$B_C = \begin{bmatrix} C_1/C_1 & C_1/C_2 & C_1/C_3 \\ C_2/C_1 & C_2/C_2 & C_2/C_3 \\ C_3/C_1 & C_3/C_2 & C_3/C_3 \end{bmatrix} = \begin{bmatrix} 1 & 3 & 1/2 \\ 1/3 & 1 & 1/5 \\ 2 & 5 & 1 \end{bmatrix} \tag{6}$$

The weight matrix is

$$\omega_C = \begin{bmatrix} \omega_{C1} \\ \omega_{C2} \\ \omega_{C3} \end{bmatrix} = \begin{bmatrix} 0.3090 \\ 0.1095 \\ 0.5815 \end{bmatrix} \tag{7}$$

Similarly, for criterion layer 2, the judgment matrices of geology, production performance, and engineering factors, respectively, are

$$B_{C1} = \begin{bmatrix} 1 & 3 & 2 & 4 & 5 \\ 1/3 & 1 & 3 & 2 & 2 \\ 1/2 & 1/3 & 1 & 3 & 3 \\ 1/4 & 1/2 & 1/3 & 1 & 2 \\ 1/5 & 1/2 & 1/3 & 1/2 & 1 \end{bmatrix} \tag{8}$$

$$B_{C2} = \begin{bmatrix} 1 & 4 \\ 1/4 & 1 \end{bmatrix} \tag{9}$$

$$B_{C3} = \begin{bmatrix} 1 & 1/3 & 1/2 & 1/3 & 1 & 1/2 & 1 \\ 3 & 1 & 2 & 1 & 3 & 1 & 3 \\ 2 & 1/2 & 1 & 1 & 2 & 1 & 3 \\ 3 & 1 & 1 & 1 & 3 & 2 & 4 \\ 1 & 1/3 & 1/2 & 1/3 & 1 & 1/2 & 3 \\ 2 & 1 & 1 & 1/2 & 2 & 1 & 3 \\ 1 & 1/3 & 1/3 & 1/4 & 1/3 & 1/3 & 1 \end{bmatrix} \tag{10}$$

The weight matrices are

$$\omega_{C1} = [0.4157 \quad 0.2343 \quad 0.1816 \quad 0.0973 \quad 0.0711]^T \tag{11}$$

$$\omega_{C2} = [0.8 \quad 0.2]^T \tag{12}$$

$$\omega_{C3} = [0.0745 \quad 0.2237 \quad 0.1624 \quad 0.2314 \quad 0.0901 \quad 0.1619 \quad 0.0559]^T \tag{13}$$

Consistency Test

The weight vector represents the relative importance of each element in its layer to an element of the previous level. Whether the single ranking can be confirmed needs to be verified by the consistency test. When the consistency ratio is smaller than 0.1, the judgment matrix meets the requirements.

TABLE 2 | Corresponding values of random consistency indicators.

<i>n</i>	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.90	1.52

The consistency ratio can be calculated by the consistency test formula as follows:

$$CR = CI/RI, \tag{14}$$

where

$$CI = \frac{\lambda_{max} - n}{n - 1}. \tag{15}$$

Here, λ_{max} is the maximum eigenvalue of the judgment matrix and n is the unique nonzero eigenvalues of n -order uniform matrices. RI is the random consistency index which can be obtained by looking up **Table 2**.

The total ranking weight vector of the multilevel model can be calculated by the following formula:

$$CR = \frac{\omega_1 CI_1 + \omega_2 CI_2 + \dots + \omega_n CI_n}{\omega_1 RI_1 + \omega_2 RI_2 + \dots + \omega_n RI_n}, \tag{16}$$

where ω_i is the weight of each element.

If the consistency ratio of any layer fails to pass, it needs to be corrected again until the condition of $CR < 0.10$ is met. According to the results, the consistency ratio of criterion layer 1 is 0.0036, and consistency ratios of criterion layer 2 are 0.0792, 0, and 0.0036, respectively, which meet the requirements.

By multiplying the judgment matrices of the two criterion layers, the weights of the two layers are shown in **Table 3**.

FUZZY MEMBERSHIP MATRIX

The suitable membership functions including maximum optimal function and minimum optimal function are established to build the membership matrix.

In this study, 14 sub-factors including geological, engineering, and production performance factors are considered when using the fuzzy comprehensive evaluation model for well selection for re-fracturing. The subordination degree of each sub-factor is determined by maximum or minimum optimal type normalization, which depends on the influence of each factor on the potentiality for re-fracturing. For example, initial formation pressure has a positive influence on production after re-fracturing, the subordination degree of initial formation pressure can be obtained by the following equation:

$$F_{ij}(x_{ij}) = \begin{cases} 0 & x_{ij} \leq x_{min} \\ \frac{x_{ij} - x_{min}}{x_{max} - x_{min}} & x_{min} < x_{ij} < x_{max} \\ 1 & x_{ij} \geq x_{max} \end{cases}, \tag{17}$$

where x_{ij} is the value of a sub-factor of a single horizontal well; x_{max} is the maximum value of the single factor; and x_{min} is the minimum value of the single factor.

Similarly, the subordination degree of other seven sub-factors including oil saturation, permeability, porosity, reservoir thickness, length of horizontal portion, flowback rate, and cumulative oil production after 90 days of primary fracturing can be obtained by **Eq. 17**.

On the contrary, the larger the number of fracturing segments is in the primary fracturing, the less the volume with high oil saturation can be re-fractured. The subordination degree of the number of fracturing segments can be obtained by the following equation:

$$F_{ij}(x_{ij}) = \begin{cases} 1 & x_{ij} \leq x_{min} \\ \frac{x_{max} - x_{ij}}{x_{max} - x_{min}} & x_{min} < x_{ij} < x_{max} \\ 0 & x_{ij} \geq x_{max} \end{cases}, \tag{18}$$

where x_{ij} is the value of a sub-factor of a single horizontal well; x_{max} is the maximum value of the single factor; and x_{min} is the minimum value of the single factor.

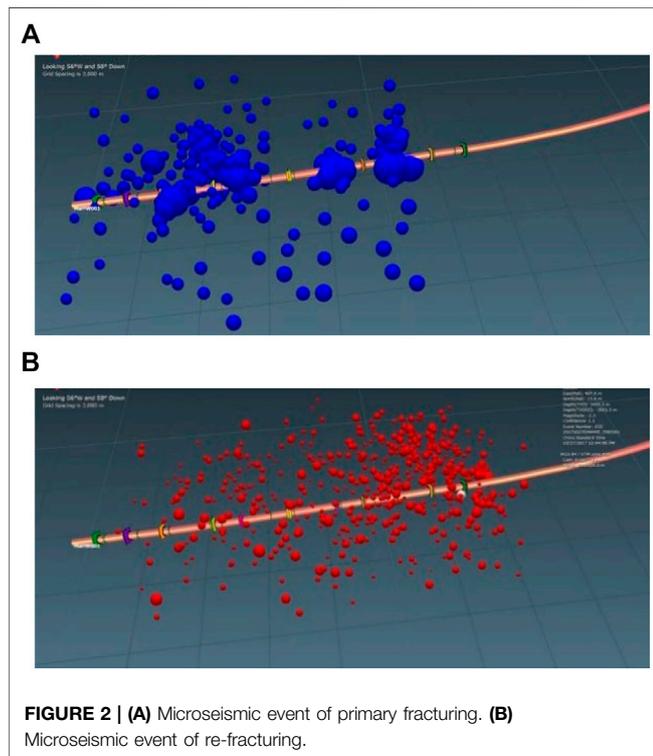
TABLE 3 | Weight distribution of the analytic hierarchy process.

Layer 1	Weight	Layer 2	Weight
Geology factors C_1	0.3090	Initial formation pressure C_{11}	0.1285
		Oil saturation C_{12}	0.0724
		Permeability C_{13}	0.0561
		Porosity C_{14}	0.0301
		Reservoir thickness C_{15}	0.0220
Production performance factors C_2	0.1095	Flowback rate after 90 days C_{21}	0.0219
		Cumulative oil production after 90 days C_{22}	0.0876
		Number of fracturing segments C_{31}	0.0433
Engineering factors C_3	0.5816	Number of clusters C_{32}	0.1301
		Rate C_{33}	0.0945
		Sand quantity of each cluster C_{34}	0.1346
		Sand ratio C_{35}	0.0524
		Liquid volume of each cluster C_{36}	0.0942
		Length of the horizontal portion C_{37}	0.0325

Fuzzy membership matrix.

TABLE 4 | Fuzzy comprehensive evaluation values of candidate wells for repeated fracturing.

Well	Fuzzy comprehensive evaluation	Well	Fuzzy comprehensive evaluation	Well	Fuzzy comprehensive evaluation
M1	0.437404	M6	0.49836	M11	0.549867
M2	0.480128	M7	0.59814	M12	0.552692
M3	0.413106	M8	0.40669	M13	0.615774
M4	0.366268	M9	0.42868	M14	0.520402
M5	0.575831	M10	0.54404	M15	0.660679



Similar to the number of fracturing segments, the subordination degree of other five factors including number of clusters, rate, sand quantity of each cluster, sand ratio, and liquid volume of each cluster can be obtained by Eq. 18.

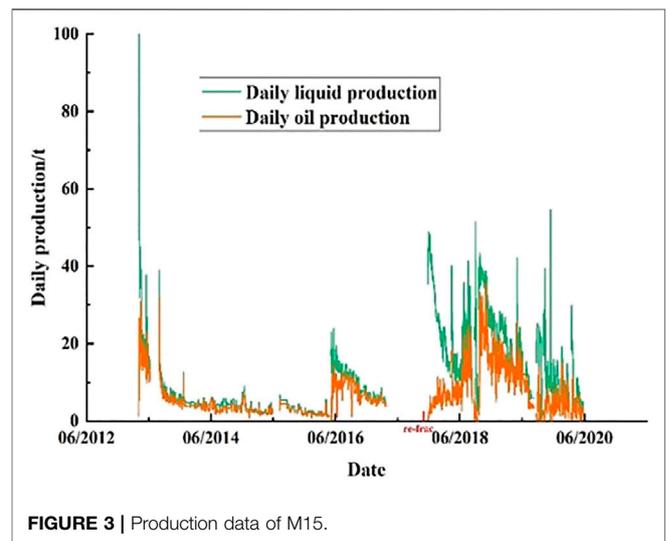
The membership matrix named as F is established as follows:

$$F = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \quad (19)$$

Assuming that ω is the weight set of factors, the comprehensive evaluation matrix is the combinatorial multiplication of the weight set with F , which can be written as follows:

$$B = (b_1, b_2, \dots, b_n) = \omega \circ F, \quad (20)$$

where



$$b_j = \sum_{i=1}^n \omega_i f_{ij}, j = 1, \dots, m. \quad (21)$$

PRACTICAL APPLICATION

In the development process of horizontal wells in the Mahu Oilfield, the production process decreases rapidly and the stable production period is short. It is necessary to conduct a re-fracturing test to improve oil production. In this study, 15 horizontal wells are selected as samples, whose parameters are shown in **Supplementary Appendix S1**. The fuzzy comprehensive evaluation model is established to select the well with potentiality for re-fracturing.

The subordination degree of each sub-factor is calculated by Eqs 17, 18, and the results are shown in **Supplementary Appendix S2**. Based on Eq. 20, the comprehensive evaluation matrix is multiplied by the weight matrix and subordination degree matrix, as shown in **Supplementary Appendix S3**. The comprehensive evaluation results are shown in **Table 4**. Among the 15 wells, M15, M13, and M7 rank the top three, and well M15 has been conducted field re-fracturing tests.

Well M15 is a horizontal well with open-hole completion located at the Ma-x block of the Junggar Basin, with a completed vertical depth of 3,419.09 m and a completed measured depth of 4168 m. The length of horizontal section is 425 m located at the

target interval of 3,676–4101 m. The reservoir permeability is 0.28–2.03 mD, the reservoir porosity is 7.51–14.74%, the initial formation pressure is 52.33 MPa, and the formation temperature is 84°C.

The primary fracturing consists of five stages with a total fluid volume of 1,678.5 m³, a total sand volume of 180.25 m³, an average fluid volume per stage of 335.7 m³, and an average sand volume per stage of 36.05 m³. The temporary plugging and diversion process are selected, and the old fractures and new fractures are re-stimulated at the same time. The re-fracturing consists of six stages in total. The microseismic monitoring results show that the microseismic event covers the whole horizontal section of well M15. As shown in **Figure 2**, compared with the microseismic monitoring of the primary fracturing, the purpose of uniform re-stimulation of the horizontal section has been achieved by re-fracturing.

As shown in **Figure 3**, the daily oil production of well M15 after re-fracturing is greatly improved, and the peak daily oil production after re-fracturing reaches 35 t/d, which is higher than 30 t/d after primary fracturing. The cumulative oil production in 4 years before re-fracturing is 6,500 t, while the cumulative oil production within 2 years after re-fracturing is 7,500 t. The re-stimulation effect is very remarkable, indicating that the method of well selection is reliable.

CONCLUSION

- 1) Among the three categories of factors affecting the productivity of horizontal wells, the influences of engineering factors are the greatest, followed by the geological factors, and the production performance after the primary fracturing is minimal.
- 2) The number of fractures and the sand quantity of single cluster are the main controlling factors in engineering factors, and the initial formation pressure is the main

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controlling factor in geology factors; there is obvious correlation between the cumulative oil production after 90 days of primary fracturing with final cumulative production.

- 3) Among the well selection samples including the 15 wells, the potentiality for re-fracturing of well M15, M13, and M7 ranks the top three.
- 4) The stimulation effect of the M15 well after re-fracturing is remarkable, which verifies the reliability of the well selection method.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

QX and XM: article ideas and research scheme. BW, GR, and JP: data collection and modeling. XY: result analysis. WD and YY: manuscript writing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenrg.2022.851582/full#supplementary-material>

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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