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Study on Adjustment Well Planning Method of Offshore Oilfields

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Abstract: In oil fields of western South China Sea, adjustment well planning is normally based on geology and reservoir analysis of each oil field, then combined with production performance and potential tapping plan, propose recent planning specifically. It has difficulty in medium and long-term planning, so that adjustment well number and production planning is difficult and inefficient. Aiming at difficult prediction in medium and long-term planning of adjustment well, this paper proposed a new prediction method of adjustment well planning which applies to oil fields of western South China Sea. According to study on oil increasing law of 74 successful adjustment wells in 17 oil fields of western South China Sea, finally gets water rising law and oil decline law of different types of adjustment wells. It can guide adjustment well number planning and production planning.

Keywords: Adjustment Well, Production Planning, Medium and Long-term Planning, Water Rising Law, Oil Decline Law

1. Introduction

At present most domestic offshore oilfields are in middle and later development period. Confronted with problems like technology and economic, in order to keep stable production of oilfields and meet oil demand of national economic development, it is necessary to determine development plan by oilfields performance law and get maximum oil production with lowest cost, which is an important problem in oilfield development planning [1, 2]. Adjustment well deployment is a key factor and effective stimulation measure in oilfield development. How to plan future yearly adjustment well number and production is essential in oilfield development planning [3]. At present there are 228 wells in oilfields of western South China Sea, including 74 adjustment wells. Adjustment wells account for 32% of all the wells, and their contribution to the whole oil production is enormously. In oilfields of western South China Sea, adjustment well planning can only propose recent planning basing on geology and reservoir analysis, production performance and potential tapping plan. There is difficulty in medium and long term planning, so it is significant to change adjustment well planning method, and make adjustment well number and production planning more effective.

In adjustment well planning of oilfield development planning decision, aiming at maximum profit as well as considering cost and investment constraints, usually establish linear or non-linear planning mathematical model of oilfield development according to actual oilfield development facts. Solve the model by genetic algorithm and then get annually adjustment well number and production distribution, which can provide quantitative decision basis of oilfield development planning in medium and short term [4-14]. In oilfields of western South China Sea, basing on geology and reservoir analysis in each oilfield, as well as combined with production performance and potential tapping plan, adjustment well planning can only propose recent planning. Medium and long term planning is difficult, so adjustment well number and production planning cannot carry on effectively. So that it will have an effect on oilfield development and adjustment.

2. New Method of Adjustment Well Planning

To solve problem of difficult medium and long term planning prediction, aiming at 74 successful adjustment wells, this paper analyzed well production law basing on well performance analysis. After statistical analysis we finally get water rising law and oil decline law of different types of adjustment wells. The new adjustment well planning prediction method is applicable in oilfields of western South China Sea.

Take infill well in marine strata as an example, adjustment well planning prediction procedure is shown in figure 1. Left procedure shows with adjustment well number we can predict their annually production. Infill well number and time of being put into production in marine strata is known. Time of being put into production is certain, combined with initial production and cumulative production law of infill well, can get their initial production and cumulative production. Then according to decline rate of marine strata, can get oil production of single well. With well number can get annually oil production. On the other hand, well number is certain, combined with water rising law of marine strata, can get their annually water production. Finally get oil and water production of infill well in marine strata. With same method right procedure shows with annually adjustment well production we can predict adjustment well number. Likewise planning prediction of other types of adjustment wells can be got with same method.

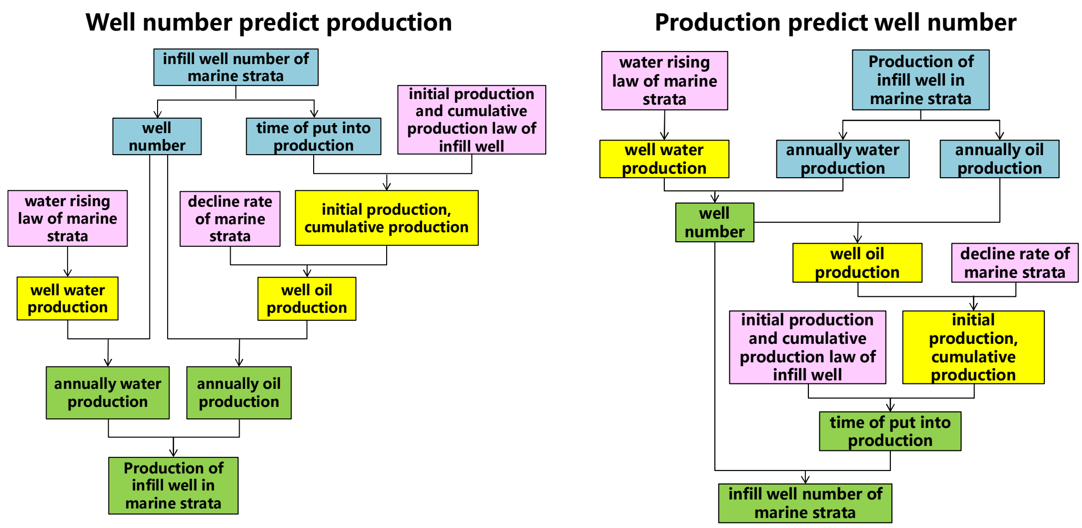

Figure 1. *Adjustment well planning prediction procedure.*

Table 1. *Classification of 74 adjustment wells in 17 oilfields of western South China Sea.*

Sedimentary face	Formation	Well deployment	Well number
marine	JW	infill	12
marine	JW	extension	3
marine	ZJ	infill	21
marine	ZJ	extension	6
marine	ZH	infill	2
continental	WZ	infill	15
continental	WZ	extension	4
continental	LS	infill	11

2.1. Classification of Adjustment Well

Classify 74 adjustment wells by different classification way (table 1). According to statistical analysis of well production data, classifying by geology and reservoir feature as well as well deployment show obvious development law. By geology and reservoir feature all the adjustment wells can be classified as adjustment wells of JW, ZJ and ZH formation in marine strata (44 wells), WZ formation in continental strata (19 wells), and LS formation in continental strata (11 wells). By well deployment all the adjustment wells can be classified as infill well (61 wells) and extension well (13 wells).

2.2. Decline Rate and Water Rising Law

By geology and reservoir feature adjustment wells can be classified as adjustment wells of marine strata, WZ formation in continental strata and LS formation in continental strata. According to comparison and analysis of well water rising curve, it is found to present convex type, S type and concave type [15-17]. Usually different water rising mode should be expressed by different equation separately. Before analyzing oilfield water rising law, firstly water rising mode should be recognized and matched. With inconvenient operation, effect is also relatively poor. This paper expressed water rising law of 3 different types of adjustment well by Logistic growth curve [18-22], which is commonly used in production forecast.

$$f_w = \frac{1}{p_1 + p_2 \times e^{(p_3 \times R + p_4)}} \quad (1)$$

In above equation: f_w——water cut;

R——recovery of recoverable reserves;

P_1, P_2, P_3, P_4——matching parameters.

Same as other empirical equation, matching parameters P_1, P_2, P_3 and P_4 have no definitive physical meaning, but have their own variation range and trend. P_3 is main controlling factor of water rising mode. When $P_1 = P_4 = 1$ and $P_2 = 50$, P_3 is decreasing gradually, and water rising curve changing from concave to convex (figure 2). When P_3 is about -10 it presents S shape.

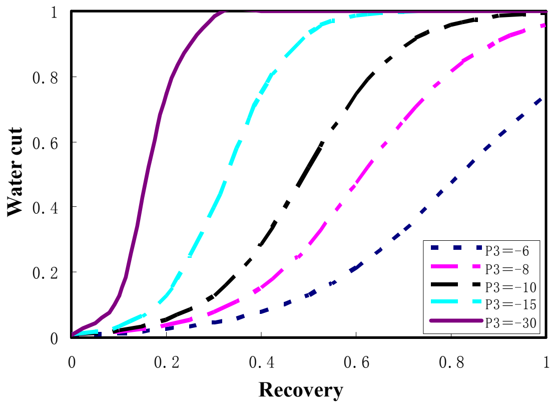

Figure 2. Matching chart of water rising curve.

Match average well water rising mode of adjustment well in marine strata (figure 3) by Logistic growth curve, and establish relation between water cut and recovery:

$$f_w = \frac{1}{1.05 + 1.6 \times e^{(-16 \times R + 3.2)}} \quad (2)$$

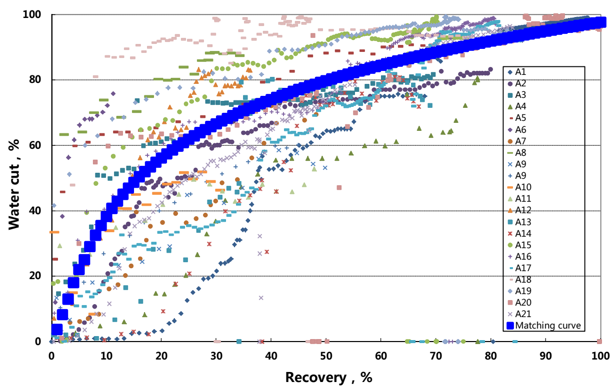

Figure 3. Relation curve between water cut and recovery of adjustment wells of JW formation, ZJ formation, ZH formation in marine strata.

By same method match well water rising mode of adjustment wells of WZ formation in continental strata (figure 4), and establish below relation between water cut and recovery:

$$f_w = \frac{1}{1.05 + 5e^{(-8R + 2.5)}} \quad (3)$$

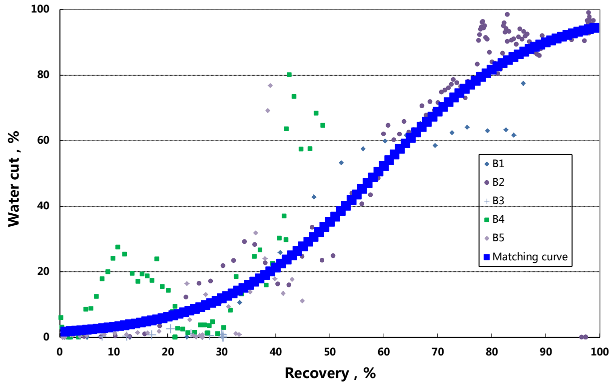

Figure 4. Relation curve between water cut and recovery of adjustment wells of WZ formation in continental strata.

At last match well water rising mode of adjustment wells of LS formation in continental strata (figure 5), and establish below relation between water cut and recovery:

$$f_w = \frac{1}{1.4 + 60e^{(-6R + 2.3)}} \quad (4)$$

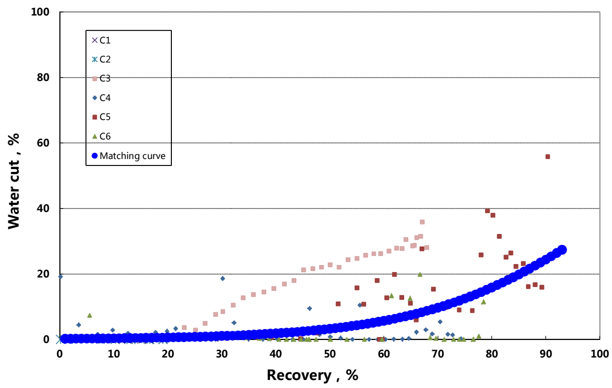

Figure 5. Relation curve between water cut and recovery of adjustment wells of LS formation in continental strata.

According to well daily oil production of 3 different types of adjustment well (figure 6~figure 8), match well oil decline law of every type. Then get oil decline rate of different development stage, which is shown in table 2.

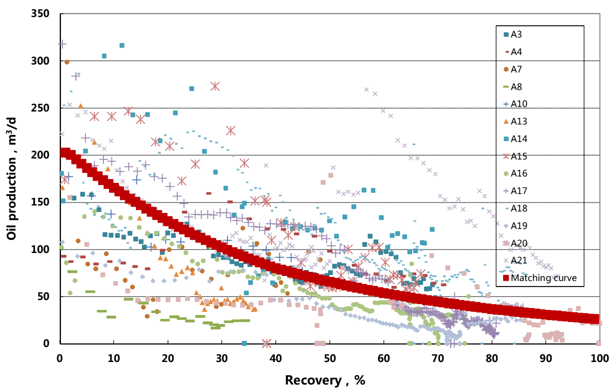

Figure 6. Relation curve between production and recovery of adjustment wells of JW formation, ZJ formation, ZH formation in marine strata.

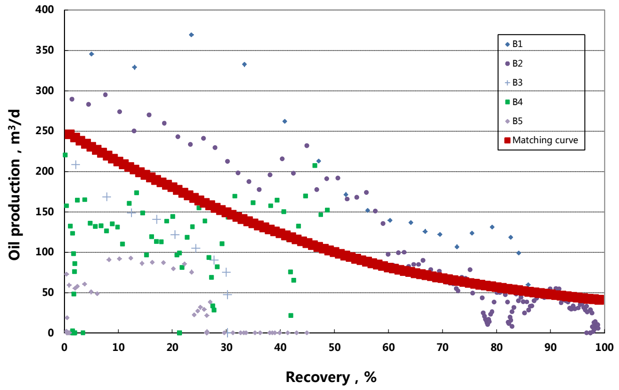

Figure 7. *Relation curve between production and recovery of adjustment wells of WZ formation in continental strata.*

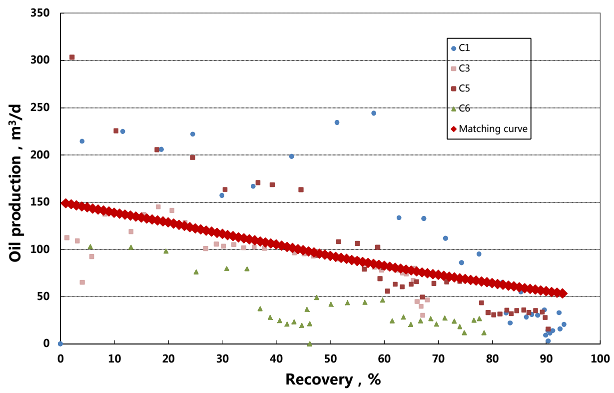

Figure 8. *Relation curve between production and recovery of adjustment wells of LS formation in continental strata.*

Table 2. *Water rising law and oil decline rate in adjustment wells of 3 different formations.*

Sedimentary face	Formation	Oil decline rate of different recovery				
		R<20	20<R<40	40<R<60	60<R<80	R>80
marine	JW, ZJ, ZH	0.024	0.024	0.020	0.019	0.018
continental	WZ	0.016	0.019	0.021	0.018	0.017
continental	LS	0.008	0.010	0.012	0.013	0.014

2.3. Initial Production and Cumulative Production Law

According to well deployment method adjustment well is divided into infill well and extension well. Analysis shows that initial production and cumulative production of different type of adjustment well are negatively related to time of being put into production. Due to influence like producing degree, oil saturation, water influx and pollution, generally the later adjustment wells are put into production, the lower initial production and cumulative production are. Statistics infill wells which were put into production every year (figure 9), and match a decline relation with time of being put into production:

$$Q = 294.22e\left[-0.064(t-1998)\right] \tag{5}$$

In above equation: Q——initial production, m^3/d; t——year of being put into production.

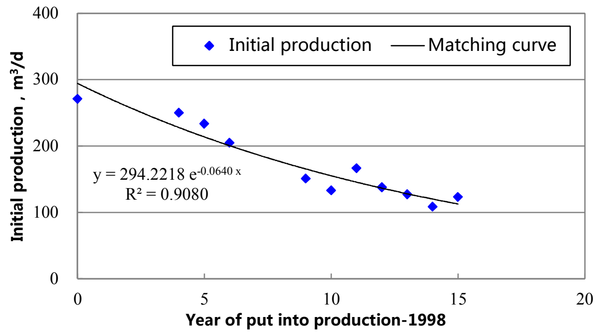

Figure 9. *Relation curve between initial production and being put into production time of infill well.*

By same method statistics average well initial production of extension well which were put into production every year (figure 10), and match a decline relation with time of being put into production:

$$Q = 160.22e\left[-0.060(t-2006)\right] \tag{6}$$

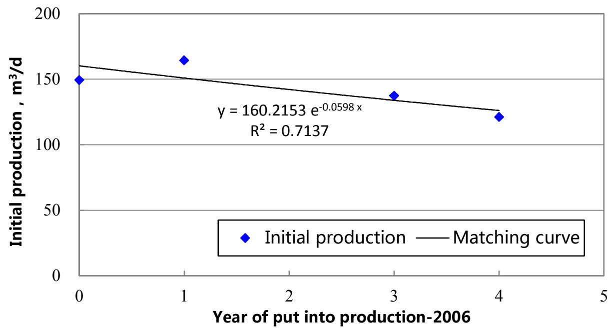

Figure 10. *Relation curve between initial production and being put into production time of extension well*

According to average well cumulative production of infill well which were put into production every year (figure 11), match a decline relation with time of being put into production:

$$N = 57.18e\left[-0.095(t-1998)\right] \tag{7}$$

In above equation: N——cumulative production, $10^4 m^3$; t——year of being put into production.

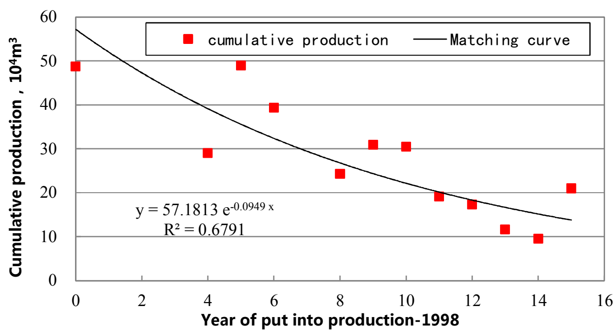

Figure 11. *Relation curve between cumulative production and being put into production time of infill well.*

According to average well cumulative production of extension well which were put into production every year (figure 12), match a decline relation with time of being put into production:

$$N = 39.33e\left[-0.091(t-2006)\right] \quad (8)$$

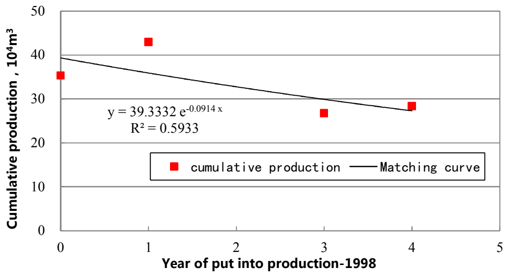

Figure 12. *Relation curve between cumulative production and being put into production time of extension well.*

Because offshore oilfields are usually development adjusted by drilling sidetracking well, select them from infill well and extension well, and then study variation law of initial production and cumulative production with same method.

According to average well initial production of sidetracking well which were put into production every year (figure 13), match a decline relation with time of being put into production:

$$Q = 262.71e\left[-0.057(t-1998)\right] \quad (9)$$

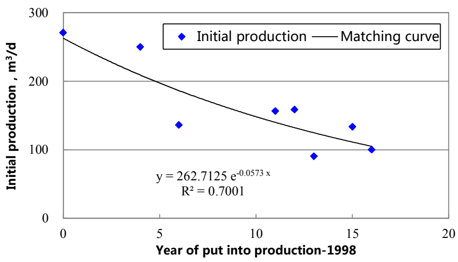

Figure 13. *Relation curve between initial production and being put into production time of sidetracking well.*

According to average well cumulative production of sidetracking well which were put into production every year (figure 14), match a decline relation with time of being put into production:

$$N = 33.92e\left[-0.079(t-1998)\right] \quad (10)$$

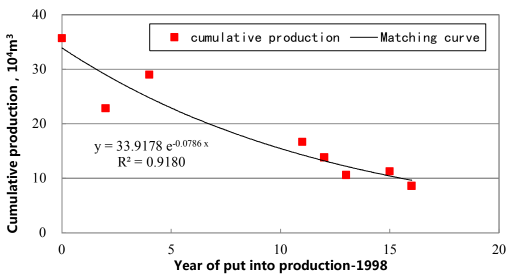

Figure 14. *Relation curve between cumulative production and being put into production time of sidetracking well.*

In summary if adjustment well type and time of being put into production are determined, average well initial production and cumulative production can be got. Combined with previous decline rate can get annually oil production of the well since being put into production. With water rising law of different type of adjustment well, can get annually water production of the well since being put into production. In development planning the method can provide guidance to medium-long term planning of adjustment well number and production.

3. Example Application

With previous oil decline law and water rising law of adjustment well, we can plan adjustment well number and production in oilfields of western South China Sea. We can predict production with adjustment well number planning. For example, if annually adjustment well number planning of oilfields in western South China Sea in 2017~2030 is known, assume X infill wells of marine strata are put into production in 2017. Then substitute it in equation (5), initial production of infill well is determined. And substituted in equation (7), average well cumulative production is determined. To sidetracking well separately substitute year of put into production in equation (9) and equation (10), initial production and cumulative production of sidetracking wells are determined. Combined with decline rate of infill well in marine strata shown in table 2, can get annually oil production of the X adjustment wells. With equation (2) can get annually water production of the X adjustment wells. By same method annually oil and water production of different type of adjustment well can be determined. On the contrary, adjustment well production can back calculate adjustment well number planning. If annually adjustment well production demand of oilfields in western South China Sea in 2017~2030 is known, by same method can back calculate annually adjustment well number.

4. Conclusion and Suggestion

(1) This paper established relation between water cut and recovery, as well as oil decline rate under different recovery of adjustment wells in marine strata, WZ formation of continental strata, and LS formation in continental strata.

(2) To infill well and extension well, establish relation between average well initial production and time of put into production, as well as cumulative production and time of put into production. Combine with above conclusion can predict oil and water production of adjustment well, which can solve problem of difficult prediction in medium-long term adjustment well planning.

(3) In adjustment well planning of production planning, establish relation between adjustment well number and production. It can help to predict adjustment well production by adjustment well number, as well as back calculate adjustment well number by adjustment well production.

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