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Evaluation of Statistical Error on Multi-Cup Uniform Flux Anchor application Test Results

SUN Zhe[1], ZHANG Shanshan[2]
(1. China National Offshore Oil Corporation (CNOOC) Research Institute Co., Ltd., Beijing 100028, China; 2. China University of Petroleum (Beijing), Beijing 102249, China)
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Abstract: Based on the theory of sampling error and confidence interval of multi-cup uniform flux anchor application test results, the corresponding numerical calculation method was given. The effect law of confidence level, numbers of sampling measurement wells and single well production parameter fluctuations on sampling error of multi-cup uniform flux anchor application test results was analyzed. According to the calculation method mentioned above, the sampling error and confidence interval of average daily fluid production, oil production and submergence in the first month of 190 anchor wells in the oil production company was calculated, so as to realize the statistical error evaluation of multi-cup uniform flux anchor application test results.
Key words: Sampling error; Confidence interval; Error transfer; Influence factor; Error evaluation

During the oil production process, oil wells will produce associated natural gas [1,2]. Downhole gas anchors can separate the inlet pump fluid before it enters the pump and reduce the impact of the gas on the pump, improving pump efficiency and oil well production. The conventional gas anchors used in oilfield production have eccentric gas anchors [3], screw type air anchor [4], Jia Min air anchor [5], swirl air anchor [6], and labyrinth air anchors, etc, which have short gas-liquid separation area. And the gas is easy to fill the gas anchors in the separation process, and the separation effect is not very good. The multi-cup uniform flux anchor is based on the difference in oil and gas density, and the degassing efficiency of the gas anchor is improved by extending the residence time of the oil well produced fluid in the settlement cup [7].

Therefore, the multi-cup uniform flux anchor has been more and more widely used, and the evaluation of its application effect is not only heavy workload, but also related to the promotion prospect of the multi-cup uniform flux anchor in the oilfield. Therefore, it is of theoretical and engineering significance to carry out the statistical error evaluation of the application test effect of the multi-cup uniform flux anchor.

I. THEORETICAL BASIS

1.1 Definition

Definition 1: Confidence interval: Assume that population X has evaluated parameters θ. $X_1, X_2, \cdots, X_n$ is a simple random sample with a capacity of n from the population. Two statistics θ_1 and θ_2 are established, $\theta_1 \le \theta_2$, α is a given probability, which is called significance level, $1-\alpha$ is called the confidence level. If $p\left(\theta_1 < \theta < \theta_2\right) = 1-\alpha$ is true, the random interval $\left(\theta_1, \theta_2\right)$ is called the confidence interval of the parameter at the confidence level. Then the random interval is called the confidence interval of the parameter θ at the confidence level $1-\alpha$.

Definition 2: Sampling error: the interval length $\theta_2 - \theta_1$ of the confidence interval is called the estimation accuracy, which is recorded as $2\Delta x$, that is $2\Delta x = \theta_2 - \theta_1$, Where Δx is the sampling error. The shorter the confidence interval, the higher the estimation accuracy and the smaller the sampling error.

Definition 3: $\overline{X}$ and s^2 are the sample mean and the sample variance [8]:

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad (1)$$

1.2 Sampling error and confidence interval

When the population variance σ^2 is unknown, let $X_1, X_2, \cdots, X_n$ be a sample that obeys the population $N(\mu,\sigma^2)$. Since σ^2 is unknown, we usually use sample variance s^2 to estimate population variance σ^2. The statistic $T=\frac{\overline{X}-\mu}{s/\sqrt{n}}\sim t(n-1)$, for a given significance level α, the two-sided critical value $t_{\alpha/2}(n-1)$ of μ can be determined according to the t distribution table, which makes $P\left\{\left|\frac{\overline{X}-\mu}{s/\sqrt{n}}\right|<t_{\alpha/2}(n-1)\right\}=1-\alpha$ become true. The confidence level of population μ obtained by $p\left\{\overline{X}-\frac{s}{\sqrt{n}}t_{\alpha/2}(n-1)<\mu<\overline{X}+\frac{s}{\sqrt{n}}t_{\alpha/2}(n-1)\right\}=1-\alpha$ is $1-\alpha$, and the confidence interval is [9]:

$$\left(\overline{X}\pm\frac{s}{\sqrt{n}}t_{\alpha/2}(n-1)\right) \tag{3}$$

And

$$\Delta x=|\overline{X}-\mu|=\frac{s}{\sqrt{n}}t_{\alpha/2}(n-1) \tag{4}$$

Where, Δx is sampling error, dimensionless.

1.3 Error transmission

Let x^* be an approximation of the exact number x, then the difference or the absolute value of the difference is given as follows:

$$\Delta(x^*)=x^*-x \tag{5}$$

That is the absolute error of approximate number x^*, also, the calculated sampling error Δx.

The formula of sampling error of $x_1^*\pm x_2^*$ is as follows [10]:

$$\Delta(x_1^*\pm x_2^*)=\Delta(x_1^*)\pm\Delta(x_2^*) \tag{6}$$

The formula of sampling error of $\frac{x_1^*}{x_2^*}$ is as follows:

$$\Delta\left(\frac{x_1^*}{x_2^*}\right)=\frac{x_2^*\Delta(x_1^*)-x_1^*\Delta(x_2^*)}{(x_2^*)^2} \tag{7}$$

II. CALCULATION METHOD

1) Scientific and reasonable determination of sampling measurement of the number of Wells n, to ensure the accuracy of the calculation and the maximum effect of sampling inference;

2) To reasonably determine the confidence level $1-\alpha$, the requirements for the accuracy and reliability of the estimation should be considered according to the actual situation of the field. According to the actual situation, the confidence level $1-\alpha$ was set as 90.0%;

3) Calculate the sampling index of the sample, and calculate the sample average $\overline{X}$ of the monthly liquid production, oil production and submergence data after the gas anchor is installed according to formula (1). According to formula (2) to calculate the sample standard deviation $\overline{s}$ of each month's liquid production, oil production and submergence data after the gas anchor is installed, and the calculated sample average and sample standard deviation are used as the estimated value of the overall index;

4) According to the given confidence level $1-\alpha$ and the number of wells n sampled and measured, the value is obtained by the statistical function TINV or by consulting the t distribution table;

5) Formula (4) is used to calculate the sampling error Δx of the sample mean value of the monthly liquid production, oil production and submergence data after gas anchor, and formula (3) is used to calculate the upper and lower limits of the estimated population index, that is, the confidence interval of the population index μ with the confidence level of $1-\alpha$;

6) According to the error transfer formula (6) or (7), the sampling errors of monthly liquid production ratio, oil production ratio and submergence ratio, and the sampling errors of monthly liquid production ratio difference,

oil production ratio difference and submergence ratio difference are calculated.

III. INFLUENCE FACTOR

1）The influence of confidence level

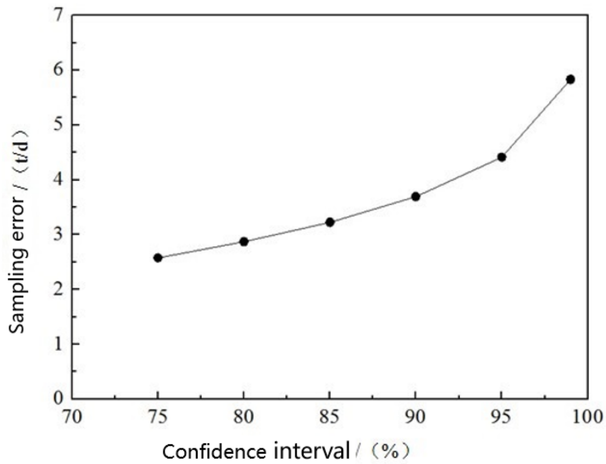

Fig.1 Relationship between sampling error and confidence interval

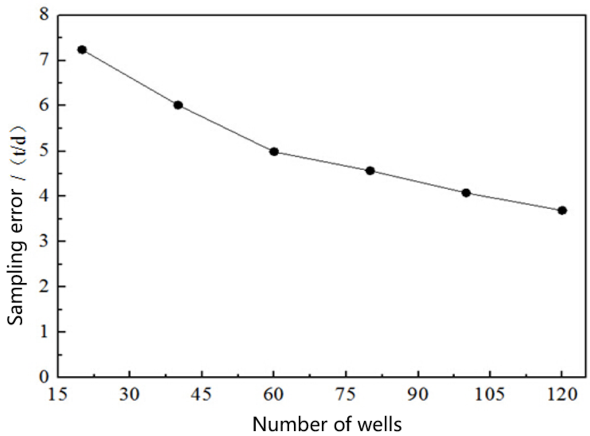

Fig.2 Relationship between sampling error and numbers of sampling measurement wells

The confidence level refers to the probability that the population parameter value falls in a certain area of the sample statistical value. When the number of sampling wells and the fluctuation range of single well production parameters are the same, the sampling error Δx under different confidence levels is shown in Fig. 1.

As can be seen from Fig. 1, with the increase of the confidence level, the sampling error shows an upward trend, and the confidence interval expands.

2）Influence of sampling survey on the number of wells

When the confidence level and the fluctuation range of single well production parameters are the same, the sampling error Δx under different sampling measurement well number conditions is shown in Fig. 2.

It can be seen from Fig. 2 that with the increase of the number of sampling survey wells, the sampling error shows a downward trend and the confidence interval decreases. If the number of sampling survey wells is more, the sample structure is closer to the overall structure, and the sample is more representative to the overall structure.

3）Influence of single well production parameters fluctuation amplitude

The fluctuation range of production parameters of single well refers to the difference between the monthly data of liquid production, oil production and submergence degree and the average value of samples, which is used to measure the fluctuation of sample data. When the confidence level and the number of sampling measurement wells are the same, the sampling error Δx under different fluctuation amplitude of single well production parameters is shown in Fig. 3.

It can be seen from Fig. 3 that with the increase of fluctuation amplitude of production parameters of single well, the sampling error shows an upward trend and the confidence interval expands.

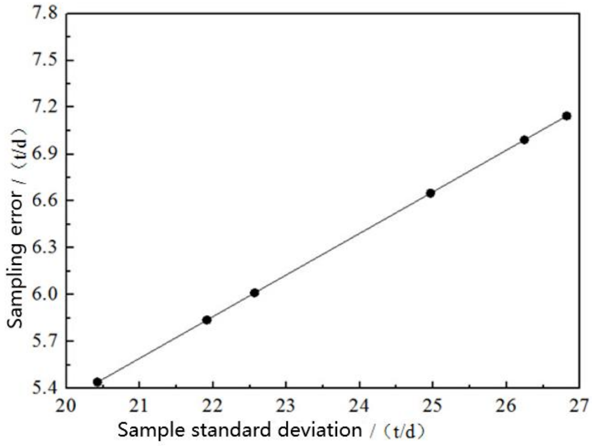

Fig.3 Relationship between sampling error and single well production parameter fluctuations

IV. CALCULATION EXAMPLES

According to the theoretical basis and numerical calculation method of sampling error and confidence interval of application test effect of multi-cup uniform flux anchor, the sampling error and confidence interval of liquid production, oil production and submergence degree of a certain oil production plant after putting multi-cup uniform flux anchor are calculated under the condition of 90.0% confidence level, as shown in Table 1, so as to realize the application test of multi-cup uniform flux anchor in an oil production plant.

Table 1 Sampling error of daily fluid production, oil production and submergence data of 190 gas anchor wells

Project	Pump inspection well	Gas anchor well	Pump inspection well ratio（7M）	Gas anchor well ratio（7M）	Difference between pump inspection well and gas anchor well ratio
Daily liquid production /t	49.9370±1.6318	56.5758±3.0729	1.0321±0.0206	1.0807±0.0315	0.0486±0.0109
Daily oil production /t	3.6620±0.1556	3.7716±0.2564	0.9375±0.0205	1.0514±0.0150	0.1139±0.0055
Submergence /m	161.2654±8.4643	157.5570±16.2833	0.6341±0.0088	0.6391±0.0172	0.005±0.0084

V. CONCLUSION

1)The theoretical basis and numerical calculation method of confidence interval and sampling error of multi cup equal flow pattern gas anchor application test effect are given;

2) The influence law of confidence level, number of sampling wells and fluctuation amplitude of single well production parameters on sampling error of multi-cup gas anchor application test is analyzed;

3)According to the above calculation method, the sampling error and confidence interval of average daily liquid production, oil production and submergence degree in the first month of 190 gas anchor wells in an oil production plant are calculated, so as to realize the statistical error evaluation of multi cup equal flow pattern gas anchor application test effect.

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