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OPTIMIZATION STUDY OF COMBINATION ENERGY-SAVING MEASURE FOR MECHANICAL OIL PRODUCTION WELL

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ABSTRACT

In this paper, Fibonacci optimization-searching method and Golden section method are applied for optimization of combination energy-saving measure. And technology evaluating for several main energy-saving equipment and combination installations is made. The optimal energy-saving installation is determined by using the method established.

INTRODUCTION

Though the combination energy-saving measure for mechanical oil production well plays a very important role in improving the whole economic efficiency of the oil field, it does not reach to the optimal saving status. Except for the increasing inputs of saving measure, optimizing of the combination of kinds of saving equipment and technology is needed for enhancing the economic efficiency of the combination energy-saving measure for mechanical oil production well. So as to realize the good consistence of quality with efficiency.

OPTIMIZATION THEORY OF COMBINATION ENERGY-SAVING MEASURE[1][2][3]

Fibonacci Optimization-Searching Method

Fibonacci is a group of numbers with the following conditions.

$$F_0 = F_1 = 1$$
$$F_n = F_{n-1} + F_{n-2}$$
$$n = 2,3,\cdots\cdots$$

Then F_n can be calculated by the formula stated above in order.

n	0	1	2	3	4	5	6	7	8	9	10	...
F_n	1	1	2	3	5	8	13	21	34	55	89	...

Where the following law exists

$$F_{n-1}/F_{n+1} + F_n/F_{n+1} = 1$$

Selecting two start points in the searching interval, that is:

$$x_1 = F_{n-1}/F_{n+1} \quad , \quad x_2 = F_n/F_{n+1}$$

Which fits to the following express:

$$x_1 + x_2 = (F_{n-1} + F_n)/F_{n+1} = 1$$

Where x1 and x2 is symmetry with each other about interval[0，1].

Case f(x1)≤f(x2)，extreme point falls to [0,x2]，x1 is the reserved point.

Case f(x1)>f(x2)，extreme point falls to [x1,1]，x2 is the reserved point.

In the two cases above，the lengths of the searching interval decrease to （x2-0） or （1-x1） from 1 respectively. They both equals Fn / Fn+1 and is symmetry. Then this kind of interval searching, which is not lacking of universality, is lessened according to symmetric principle.

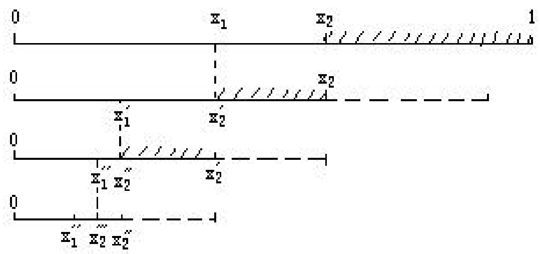

Fig. 1 Interval decreased optimization-searching diagram

First time: The supposed interval is [0，x_2], the original interval is [0，1]，then the shorten ratio is given by

The shorten ratio = "[0，x_2]" / "[0，1]" = F_n / F_{n+1}

Second time: The supposed interval is [0，x_2'], the original interval is [0，x_2]，then

The shorten ratio = "[0，x_2']" / "[0，x_2]" = F_{n-1} / F_n

…………

The nth time：The shorten ratio =…= F_1 / F_2=1/2

Through n times calculation of the object function value, the shorten ratio of each interval is as follows in turn:

Fn/Fn+1 ，Fn-1/Fn ，Fn-2/Fn-1 ，…,F2/F3 ，F1/F2（=1/2）

Through n times calculation of the object function value, the total shorten ratio of the reserved interval is:

(Fn/Fn+1) · (Fn-1/Fn) · (Fn-2/Fn-1) · … · (F2/F3) · (F1/F2) = F1/Fn+1=1/Fn+1

Golden Section Method

Suppose we have the following array

F_n/F_{n+1} , F_{n-1}/F_n , F_{n-2}/F_{n-1} , …, F_2/F_3 , F_1/F_2

The above array can be divided into the following two sub-arrays $\{F_{2k-1}/F_{2k}\}$,$\{F_{2k}/F_{2k+1}\}$.

Suppose

$$\lim_{k\to\infty}\frac{F_{2K-1}}{F_{2K}} = l \qquad \lim_{k\to\infty}\frac{F_{2K}}{F_{2K+1}} = m$$

Since

$$\frac{F_{2k}}{F_{2k+1}} = \frac{F_{2k}}{F_{2k}+F_{2k-1}} = \frac{1}{1+\frac{F_{2k-1}}{F_{2k}}}$$

Applying limit to the two formulas above

$$m = \lim_{k\to\infty}\frac{F_{2k}}{F_{2k+1}} = \lim_{k\to\infty}\frac{1}{1+\frac{F_{2k-1}}{F_{2k}}} = \frac{1}{1+l}$$

Similarly, we obtain

$$l = \frac{1}{1+m}$$

Substituting its value for m in the above equation, we obtain

$$l = \frac{1}{1+\frac{1}{1+l}} = \frac{1+l}{2+l}$$

i.e.,

$$l^2 + l - 1 = 0$$

Solving the equation, we have

$$l = \frac{\sqrt{5}-1}{2}$$

Based on the same ground, we obtain

$$m = \frac{\sqrt{5}-1}{2}$$

Thus, we have

$$l = m = \frac{\sqrt{5}-1}{2} \approx 0.6180339887\ 418948 \cdots$$

The combination energy-saving measure can be divided into n levels by using golden section method, then determine the highest electricity-saving ratio of different combinations. Through the deriving we know that the cumulative

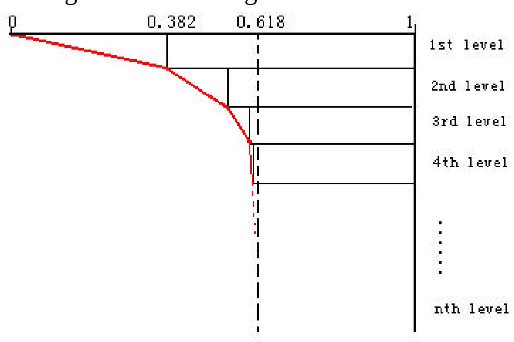

Fig. 2 Golden section method diagram

electricity-saving ratios would not extra 61.8% no matter how many combinations of energy-saving measure are adopted. And the electricity-saving ratio becomes lower with the increasing of the items. In theory, if every measure approaches to the perfect condition, three main energy-saving measures are enough for one pumping well. There usually combinations of two of the three are applied for in field.

TECHNOLOGY EVALUATING FOR MAIN ENERGY-SAVING EQUIPMENT

Main energy-saving equipment refer to energy-saving beam unit, energy-saving motor and energy-saving control pod[4][5].

Technology Evaluating For Energy-Saving Beam Unit

Three kinds of beam unit and its energy-saving theory are demonstrated in this paper.

a. Pendulum beam unit

Change the variable law of beam unit torque factor through second balance, and achieve balance strengthening, so as to reach to the aim of energy-saving.

b. Eccentric cam beam unit

On the condition that crankshaft net comment of torque is projected, taking linking of connection rod as the basement, change the motion characters of organization through optimizing the structure of crank and connection rod, then achieve energy-saving.

c. Double tetrad-bar beam unit

To improve the energy-saving effectiveness of first balance beam unit based on the structure superiority of double tetrad-bar. Starting from improvement of balance and dynamic property.

Through comprehensive evaluating and optimizing to the several energy-saving beam unit stated above with structure designing、energy-saving theory、mechanical performance、electricity-saving effectiveness and economic efficiency, we think pendulum beam unit as the best one whose investment recovery life is shortest.

Technology Evaluating For Energy-Saving Motor

Here we talk about four kinds of energy-saving motor and their energy-saving theory.

a. Super-high rotary-difference motor

Mechanical performance is soft and peak moment of torque decreases. But rotator losses largely and creates heat easily.

b. CJT series dragging installation.

It's a combination of super-high rotary-difference motor and control pod. Its start-up electric current is small and moment of torque is large.

c. DFCJT dragging installation

It's also a combination-integrated body of super-high rotary-difference motor and control pod. Its control part is of type of 0.66Kv anti-stolen. Its start-up electric current is small and moment of torque is large.

d. Variable-stage multi-speed motor.

The property of Variable-stage multi-speed can decrease volume and improve system matching. But feedback electric current needs to be released by electric discharge.

Technology Evaluating For Energy-Saving Control Pod

In this paper, five kinds of electricity-saving function to energy-saving control pod are proposed simply.

a. Save electricity by stator winding wye-delta converting transformation + power-factor controller regulating pressure.

b. Save electricity by stator winding wye-delta converted transformation + dynamic reactive compensation.

c. Save electricity by stator winding wye-delta converted transformation + static reactive compensation.

d. Save electricity by static reactive compensation only.

e. Save electricity by power-factor controller regulating pressure only.

EVALUATION OF COMBINATION ENERGY-SAVING TECHNOLOGY

Energy-saving combination measure for pumping well contains mainly combination of energy-saving beam unit and energy-saving control pod and combination of energy-saving motor and energy-saving control pod. We evaluate these two combinations using optimization method.

Combination Of Energy-Saving Beam Unit And Energy-Saving Control Pod

Testing comparison with two wells shows that active electricity-saving rate of installation is 40.88%, reactive electricity-saving rate is 50.18% and comprehensive electricity-saving rate is 42.99%.

Combination Of Energy-Saving Motor And Energy-Saving Control Pod

a. JNFQ beam unit series with 0.66Kv energy-saving and anti-stolen integrated power distribution installation

It contains mainly DFCJT energy-saving and anti-stolen integrated dragging installation and DFS9RB energy-saving and anti-stolen integrated transformer. These two parts compose enclosed an energy-saving and anti-stolen system.

Testing comparison of DFCJT energy-saving and anti-stolen integrated dragging installation with fifteen wells shows that active electricity-saving rate of installation is 19.99%, reactive electricity-saving rate is 37.33% and comprehensive electricity-saving rate is 23.29%.

Testing comparison of DFS9RB energy-saving and anti-stolen integrated transformer with two wells shows that transformer power factor increases 0.5695 and active loss rate decreases 3.325%.

b. CDJT variable-stage multi-speed beam unit with energy-saving dragging installation

It contains mainly variable-stage multi speed high rotary difference three-phase asynchronous motor and energy-saving control pod.

Testing comparison of CDJT integrated dragging installation with three wells shows that active electricity-saving rate of installation is 13.39%, reactive electricity-saving rate is 42.07% and comprehensive electricity-saving rate is 20.29%.

Thus we can determine from the result that combination of energy-saving beam unit and energy-saving control pod is better than another combination.

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