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Some Methods and Algoriths for Evaluation of Well Equipment and Regime Parameters in Rod, Depth Pump Oil Wells

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Abstract: The article develops methods and algorithms using the construction and fuzzy evaluation of experimental distribution functions of dynamograms to evaluate the selection of well equipment and modes in the diagnostic and control systems of rod, deep pump oil wells. Informative identification signs were formed from the values of the experimental distribution function of dynamograms. A measure of proximity between the informational characteristics of the wells selected as the reference and the wells whose current status will be determined was determined, and the identification algorithm of dynamograms and wells was given by this measurement.

Several modes were selected for fuzzy assessment of well equipment and mode selection and appropriate mebership functions were identified. Examples of valuation rules using the values of mebership functions have been identified. The article presents fragments of software modules created.

Keywords: Dynamogram, experimental distribution function, filling percentage, informative signs, proximity size, identification, mebership function, fuzzy evaluation, fuzzy rules.

1. Introduction

It is known that supervise, diagnostic and control systems created for oil companies receive information from various sources to assess the technical condition of the means, equipment and systems in operation. Such sources of information include values of technological regime parameters, data from measuring devices and systems used directly and indirectly to measure productivity, data from systems and systems used to assess the technical condition of underground and surface equipment of oil wells, and other data sources.

Dynamograms and wattograms are used to assess the technical condition of underground and surface equipment of oil wells. Dynamograms are graphs of the dependence of the hanging force on the path at which the barbell is hung. Many studies analyze the shape and various characteristics of dynamograms. In many cases, the analysis of the force acting on the suspension point as a separate signal and as a time sequence is involved in the study. By analyzing the dynamograms, valuable information can be obtained about the depth pump, rod column, oil pipes and well operating modes [1, 2]. Some sources state that up to 21 different types of faults can be identified using dynamograms [3]. However, the analysis of dynamogram forms gives satisfactory results when assessing the technical condition in shallow wells. Recently, technology, methods and algorithms for the analysis of dynamograms taken from wells at any depth have been developed. The following technologies, methods and algorithms have been developed recently:

Construction of experimental distribution functions of dynamograms, experimental distribution densities and identification of dynamograms according to the obtained results [4].

However, regardless of the results of the generated analytical methods, it is possible to explicitly or implicitly fuzzy estimate the selected mode parameters, and in many cases this estimate occurs. Here, of course, the correspondence of the selected pump type, pumping depth and number of revolutions per minute to the well drilling and perforation depth and productivity can be assessed fuzzy with a linguistic variable. We approximate the correspondence of the selected mode parameters to the technical and technological parameters of the well as a set of values of the linguistic variable.

$$LRP = \{not\ compatible, poor\ compliance, moderate\ compliance, strict\ compliance, full\ compliance\}$$

can be defined as. LRP here refers to Linguistic Regyme Parameters. You can also increase the number of elements here. However, when an mebership function is created for each mode parameter in this set, the values will be set indefinitely in the range [0.1]. [5-8]

One of the most important sources of information is the views of the operational staff on the control, diagnostics and management systems formed during the operation, prevention and maintenance. These views can be considered quite objective about the reliability and efficiency of existing systems. The article presents algorithms for setting the distribution functions of dynamograms and a method for fuzzy evaluation of the selected mode parameters to assess the technical condition of rod-type, deep-pump oil wells operating in oil companies.

2. Problem statement

Technological mode parameters must take into account the parameters selected for a particular oil production method. For oil wells with rod, depth pump, such parameters are the type of pump, the structure of the rod column, the depth of pumping, the number of revolutions per minute. Based on the values of these parameters, the theoretical productivity of the oil well can be calculated.

$$Q = 1440\frac{\pi d^2}{4}S_{pl} * n \qquad (1)$$

here, 1440 is the number of minutes per day, d is the diameter of the pump plunger, S is the path at the point where the rod column hangs, S_pl is the path of the plunger, and n is the number of cycles per minute. With the help of this formula, the volume of liquid extracted from an oil well in a day during a period of movement of the pin can be theoretically determined. Therefore, it is sometimes called instantaneous productivity. This formula can be applied only if the above-mentioned mode parameters are selected ideally and non-dynamically, and the pump is fully charged during the upward movement of the plunger. However, it is known that the actual volume of liquid extracted is determined by the motion of the plunger. This path differs from the path at the point where the bar column is suspended and can be calculated by the following formula for non-dynamic modes.

$$S_{pl} = S - \frac{q_{m*L^2g}}{E}\left(\frac{1}{f_{st}} + \frac{1}{f_{tr}}\right) \qquad (2)$$

Here S is the path of the polished rod, L is the length of the rod, - is the density of the fluid, E is the modulus of elasticity, f_{st} - is the cross-sectional area of the rod, f_{tr} - is the cross-sectional area of the oil pipe. If the oil pipes are fixed, then the second accumulation in brackets is equal to zero. It is known that in practical operation, in many cases, the pump is not fully charged. Therefore, the productivity calculated by formulas (1) - (2) must be multiplied by the percentage of filling

Individual and group measuring instruments and devices are used to measure productivity. Group measuring devices such as Trap or Ozna are mainly used in onshore oil fields in Azerbaijan [2].

New algorithms can be developed to determine productivity using noise analysis theory [9].

3. Construction of experimental distribution functions of dynamograms, experimental distribution densities and identification of dynamograms according to the obtained results.

As a result of the work of the subroutine, the dynamogram values are arranged in a regular order from small to large, and the smallest and largest values are known.

$$y_{\min} = y_1 \ \text{və}\ y_{\max} = y_M \,. \qquad (1)$$

Part $[y_{\min}; y_{\max}]$ must be divided into several equal parts to establish the experimental distribution. The number of parts was taken experimentally equal to 50 and denoted by m_50. The width of each section

$\Delta h = \dfrac{y_{\max} - y_{\min}}{m\_50}$ olar.

$y_{\max} = y_{\min} * \Delta h$ və ya $y_N = y_1 * \Delta h$.

To store the values of the distribution function accordingly
an array $i\_i \in [1, m\_50]$ olmaqla $pay\_m[i\_i]$ must be created and the elements must be pre-set to zero.

Therefore arbitrary $n \in [1, N]$ üçün elə $m \in [1, m\_50]$ that can be found,

$$y_n \in [y_1 + (m-1)*\Delta h, y_1 + m*\Delta h] \qquad (2).$$

Since $y_n \in [y_1, y_N]$ number m satisfying condition (2) is always found.

Here are the values of the experimental distribution function when we find the number m that satisfies the condition (2) for arbitrary $n \in [1, N]$.

Found as $pay\_m[m] = pay\_m[m] + 1$. In this case, the values of the auxiliary distribution function are calculated from the travel price array of the dynamogram.

$pay\_f[m] = pay\_f[m] + x[n] - x[n-1]$

The idea of the solution variant is to find the distribution of the array of forces from 0 to the maximum value, and to calculate the distribution of the array according to this distribution.

These distribution functions can be used for different purposes. The fill percentage is also calculated from the values of these functions. The values of the distribution function and the percentage of filling were realized with the help of the commands of the DELPHI VII programming system [10].

Starting from the beginning of the arrays, three steps are used to separate the movement of the lathe and, accordingly, one cycle of the dynamogram.

In the following program fragments, the departure array x1, the force array y1, the initial number of elements in the arrays n, the number after the period n_y, the power distribution pay_m, the percentage of filling are denoted by dol_f.

Three steps are used to separate a period from the beginning of the arrays. In step 4, the preparatory work for the establishment of the distribution functions, in step 5, the establishment of the distribution function, in step 6, the finding of the filling percentage, in step 7, the number of cycles of the pinch machine is determined.

Step 1: the largest and smallest values of the departure array are found:

```
x1_max:=x1[1];
x1_min:=x1[1];
for j_j:=1 to n do begin
if x1_max< x1[j_j] then x1_max:=x1[j_j];
if x1_min> x1[j_j] then x1_min:=x1[j_j];
end;
```

Step 2: it is determined that the beginning of the arrays belongs to the ascending or descending semicircle.

```
qalx_en:=0;
if (x1[10]>x1[6]) and (x1[10]>x1[5]) and
(x1[7]>x1[3]) and (x1[7]>x1[2]) then qalx_en:=1;
```

*Step*3: the part of the array corresponding to a period is separated.

```
if qalx_en=1 then begin
i_i:=n;
while x1[i_i]< x1[1] do i_i:=i_i-1;
while x1[i_i]> x1[1] do i_i:=i_i-1;
end
else
begin
x1_max:=x1[21];
i_x1_max:=21;
for j_j:=21 to n do begin
if x1_max< x1[j_j] then begin
x1_max:=x1[j_j];
i_x1_max:=j_j;
end;
i_i:=i_x1_max;
while (x1[i_i]> x1[1]) and (i_i<n) do i_i:=i_i+1;
end
end;
n_y:=i_i+1;
if n_y<100 then n_y:=n;
if n_y>n then n_y:=n;
```

*Step*4: Preparationfor the establishment of distribution functions.

```
for i_i:=1 to 100 do begin
pay_m[i_i]:=0;
pay_f[i_i]:=0;
end;
```

*Step*5: setting up distribution functions.

Find the large value of the force array and divide by m_50 to determine the distribution step d_h and calculate the values of the distribution functions. The number of m_50 was determined by practical experiments 50 <= m_50 <= 100.

```
max:=y1[1];
```

```
for i_i:=1 to n_y do begin
if max<y1[i_i] then max:=y1[i_i];
end;
d_h:=(max)/m_50;
for i_i:=2 to n_y do begin
for j_j:=1 to 100 do begin
if (y1[i_i]>=( j_j -1)*d_h ) and (y1[i_i]<( j_j)*d_h )
then
begin
pay_m [ j _ j]:=pay_m[j_j]+1;
pay_f[j_j]:=pay_f[j_j]+abs(x1[i_i]-x1[i_i-1]);
end;
end;
end;
```

Step 6: determination of filling percentage.

```
x_x:=0; y_y:=0;
for i_i:=1 to (m_50 div 2) do
begin
y_y:=y_y+ pay_f[i_i];
end;
for i_i:= (m_50 div 2) +1 to m_50 +1 do
begin
x_x:=x_x+ pay_f[i_i];
end;
dol_f:=200;
if (2*x_x-y_y)<>0 then begin
k_k:=y_y/(2*x_x-y_y);
dol_f:=trunc(100*2*k_k/(k_k+1));
end;
if dol_f>100 then dol_f:=100;
```

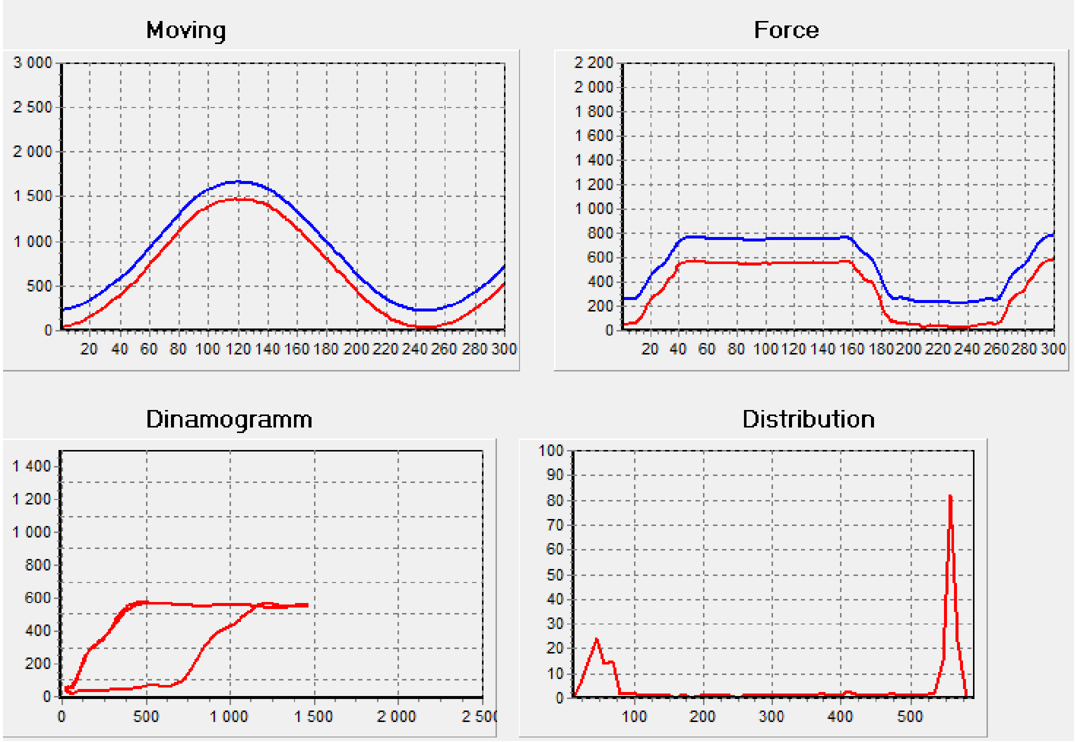
Step 7: Find the rotation time (per_iod) of the pinch machine and the number of revolutions per minute (num_n) according to the time d_t between the readings of the points..

```
per_iod:=n_y*d_t/1000;
num_n:= 60/per_iod;
```

As a result, the values of the experimental distribution function m_50 and the percentage of filling of the pump, the period of rotation of the pinch machine (per_iod) and the number of cycles per minute (num_n) are found.

The analysis of the distribution functions shows that the obtained results can be used to diagnose the technical condition of the equipment of oil wells with a rod depth pump.

The following figure shows a dynamogram of a well with a pumping depth of less than 1000 m and graphs of its distribution function. In the upper left, the first figure shows the true (red) and 80 percent smoothed (blue) of the displacement function in conventional units taken from the original converter, and the true and smoothed graphs of the force function, respectively, on the right. Below is a dynamogram for these functions on the left and a graph of the distribution density as a percentage on the right. Analysis of the dynamogram and distribution function shows that there are no technical problems in the well and that the underground equipment of the well is operating normally. However, it seems technologically that the pump filling rate is less than 60 percent. This is due to the low pumping depth or the number of revolutions per minute in the well. These problems can be easily solved.



Şəkil 1. Dynamogram and distribution function of a normally operating well with a low filling percentage.

Once the experimental distribution function of any dynamogram has been established, a small (minimum) number of informational signs must be created to solve the identification problem. The number of informational features should be small so that the solution is simple and can be easily integrated into the monitoring, diagnostic and control systems in operation at the mines. The following informative features were formed as a result of the analysis of various references and current dynamograms:

1st sign a(1)= $\sum_{j=1}^{N/3} P(j)$;

2nd sign a(2)= $\sum_{j=N/3+1}^{2N/3} P(j)$;

3rd sign a(3)= $\sum_{j=2N/3+1}^{N} P(j)$;

4th sign a (4) = Maximum value of force array - Minimum value of force array.

If necessary, the number of **symptoms** can be increased. When solving complex identification problems Instead of signs 1-3, all values of the experimental distribution function can be taken as signs.

Signs for the following 8 reference dynamograms were calculated and a table of signs for the reference dynamograms was formed..

01_e - normal dynamogram with 100% filling;
03_e - Releases the outlet valve;
04_e - Releases the inlet valve;
05_e - Sand plug;
06_e - Serious failure of the outlet valve;
07_e - Releases both valves;
10_e - Filling percentage 60 percent, normal dynamogram;
18_e - Filling percentage 80 percent, normal dynamogram.

Schedule of reference signs.

Reference Well	Character	1st sign	2nd sign	3rd sign	F_1	N_e	D_f	4th sign
01_e	**Normal**	518	62	438	0	01_e	100	140
03_e	**Exitk.b.**	500	129	395	0	03_e		54
04_e	**Entrance k.b**	234	444	346		04_e		63
05_e	**Sand plug**	448	249	321	0	05_e		118
06_e	**Exitk.**	482	150	370	0	06_e		73
07_e	**Everyi. k.**	387	282	347	0	07_e		141
10_e	**D._f, normal**	335	96	582	0	10_e	60	166
18_e	**D._f, normal**	353	96	571	0	18_e	80	171

The following information is given in this table:
Reference well – Number of reference or well;
Character - Describes the condition of the well (name of faults);
1-4th signs – Calculation of these signs are given above;
F_1- Minimum difference between the characteristics obtained from the dynamogram taken for identification and the reference characteristics. This difference in our case can be calculated as follows:

$$F\_1 = \min\left\{\sum_{i=1}^{4} abs(e\_ji - ci\_elamet - c\_i - ci\_elamet),\ j \in [1{,}8]\right\}$$

Here, the absolute value of the difference is taken as a measure of proximity. Similar results are obtained if the mean square difference or other dimensions are taken as a measure of proximity. Whichever reference meets this minimum is taken as the result of identification.

N_e- The number of the reference found as a result of identification.

D_f- Filling percentage. Given for normal and full occupancy percentages, signs of normal operation are given.

The informative signs of the reference dynamograms are included in the initialization file of the corresponding software. When the program starts, this file is read and informative signs are stored in memory. Informative signs are calculated for each new dynamogram and compared with reference information signs.

During the identification of dynamograms of some wells, it was found that the dynamograms could not be fully identified in the mining conditions. There can be several reasons for this:

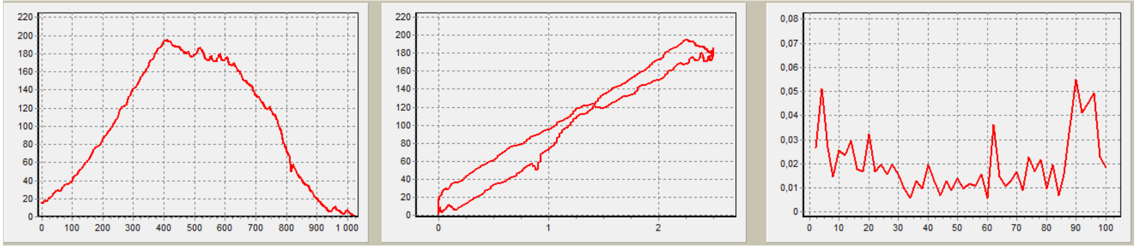
- There may be errors during identification based on visual views.
- There may be shortcomings in the mathematical and algorithmic basis of the programs used for diagnostics.
- Difficulties in identifying some hidden faults.

For an example, let's look at the table of results of the identification of the dynamogram of well 643, which was identified as a sand plug in the Kursangi mines:

Table of comparative results for well 643_s.

Etalon-Quyu	Xarakter	1-ci əlamət	2-ci əlamət	3-cü əlamət	F_1	N_e	D_f	4-cü əlamət
643_s	...	387	193	437	233	07_e		194
01_e	Normal	518	62	438	317		100	140
03_e	Exit k.b.	500	129	395	359			54
04_e	Exit k.b	234	444	346	636			63
05_e	Sand plug	448	249	321	262			118
06_e	Exit k.	482	150	370	326			73
07_e	Every i. k.	387	282	347	233			141
10_e	D._f, normal	335	96	582	322		60	166
18_e	D._f, normal	353	96	571	288		80	171

As can be seen from the table, it was found to be closer to reference 07 when identified by the results of the experimental distribution. Here the difference is 233. This reference indicates that both valves are faulty and leaking. It should be noted that there is a good reason to identify the situation as a gas plug in the mine. Thus, the difference with reference 05, which indicates the presence of a gas plug, is 262, and the difference is second only to the bottom after the minimum. The differences obtained with the references for gas plugs and valve failures are close to each other. The picture below also shows that visually the situation could be identified as a sand plug.



Şəkil 2. Force, dynamogram and experimental distribution density in well 643_s.

Analysis of the comparative results table of well 643 reveals that this well has complex problems. Here, the differences compared to different references are closer to each other.

As a measure of the complexity of the problem or the uniqueness of the assigned identification result:

$$U = \frac{1}{N\_e * N\_p} \sum_{i=1}^{N\_e} \sum_{j=1}^{N\_p} abs(M\_p(i,j) - F\_m(j))$$

can be taken.

4. Some algorithms for fuzzy evaluation of the selection of well equipment and technological modes

It is known that oil production facilities, including oil wells, are complex technical facilities. Therefore, the assessment of the selection of operating modes, technical condition or technological processes of such a facility as a whole requires a special approach. Both the fuzzy assessment of the issues raised and the assessment of the fuzzy, uncertain processes taking place at the facility require consistent approaches using a special research method. One of the main research methods is to present and analyze the large uncertainty as a set of smaller, easier to analyze and understand uncertainties in accordance with the purpose of the study, while maintaining a systematic complete picture of the object. For this purpose, we can take the depth of the pump, the percentage of filling and the degree of closeness of the diagnostic characteristics from the dynamogram distribution functions to the characteristics obtained from the dynamogram of the reference well in accordance with the normal operating mode. Simple algorithms can be created by dividing the problem into such simple parts. Let's define mebership functions by phasing each part separately.

1) t is known that the value of the pumping depth depends on the perforation depth of the well, the type of pump, the characteristics of the productive layer, etc.. In the simplest case, the pump should not be placed too deep or placed too shallow. Therefore, the membership function of this parameter can be selected in the form of a trapezoid or in the form of a Gaussian function [11, 12]. The trapezoidal affliationfunction can be given as follows. In these functions, the pumping depth is denoted by d.

$$\mu_{trapezoidal} = \begin{cases} 0, \quad d \le a \\ \frac{d-a}{b-a}, a \le d < b \\ 1\ , b \le d < c \\ \frac{d-d}{d-c}, c \le d < d \\ 0\ , d \ge d \end{cases}$$

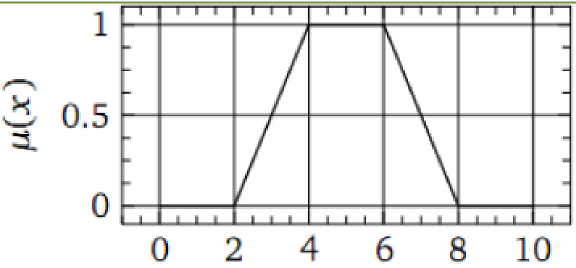


Figure 3.Trapezoidal membership function

If the membership function is selected as a Gaussian function, the function and its graph can be given as in Figure 4.

$$\mu_{Gaussian} = e^{-\frac{1}{2}(\frac{d-\mu}{\sigma})^2}$$

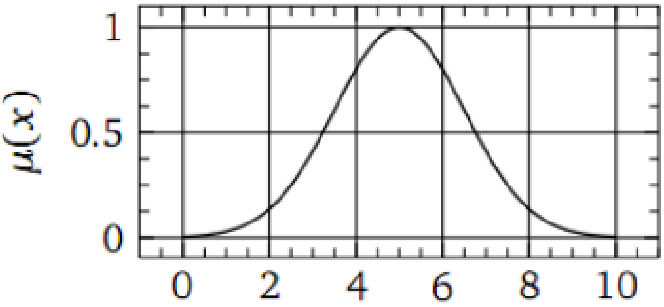


Figure 4. Gaussian membership function

Figures 3 and 4 show the values of the pumping depth divided by 100 on the axis.

Perforation depth can be applied to wells with a depth of about 1000 m. A smoother transition from one fuzzy value to another can be obtained if the Gaussian affliation function is selected.

2) The pump filling percentage can be obtained by comparing the approximate average of the actual measurements with the values obtained from formula (2) or by analyzing the dynamograms. It can be a finitely inclined linear function (Figure 5) or an S-shaped monotonically increasing sigmoidal function as a function of the percentage of filling. Here the filling percentage is denoted by p (percent).

Bounded increasing linear function

$$\mu_{Li} = \begin{cases} 0, & p < \alpha \\ \frac{p-\alpha}{b-\alpha}, & \alpha \le p < \beta \\ 1, & p \ge \beta \end{cases}$$

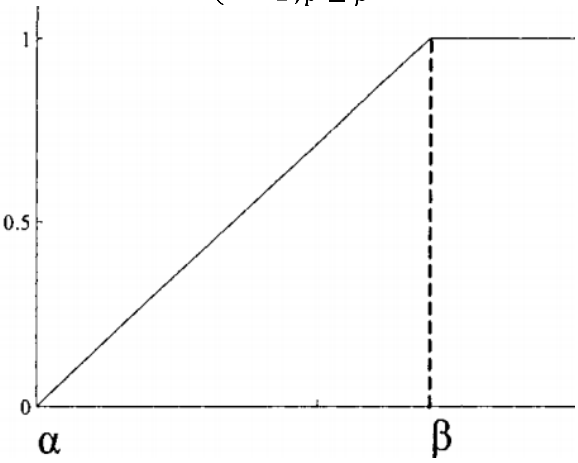
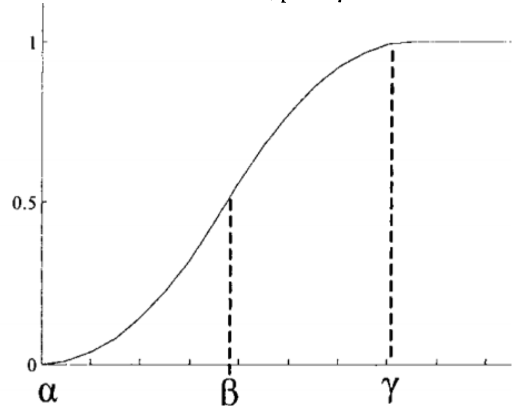


Figure 5. Bounded increasing linear membership function

S-shaped monotonous increasing sigmoidal function

$$\mu_{Si} = \begin{cases} 0, & p \leq a \\ \frac{1}{2}(\frac{p-\alpha}{\gamma-\alpha})^2, \alpha \leq p < \beta \\ 1-\frac{1}{2}(\frac{\alpha-p}{\gamma-\alpha})^2, \beta \leq p < \gamma \\ 1, p \geq \gamma \end{cases}$$

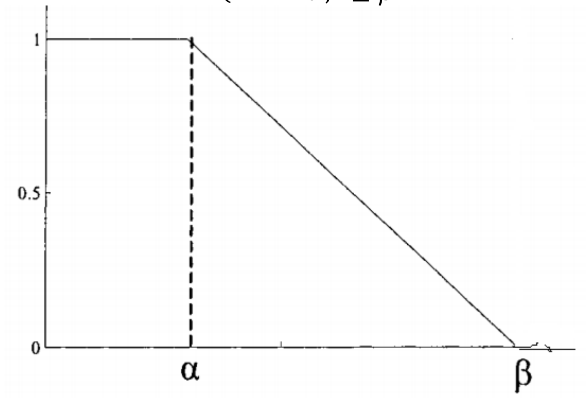


Şəkil 6. Monotonically increasing sigmoidal membership function.

3) A decreasing limited inclined function (Figure 7) or an S-shaped monotonically decreasing sigmoidal function can also be taken to estimate the degree of fuzzy proximity of the diagnostic characteristics from the distribution functions of the current dynamograms to the characteristics obtained from the dynamogram of the reference well according to the normal operating mode. Here the degree of closeness is denoted by Δ.

Bounded decreasing linear function

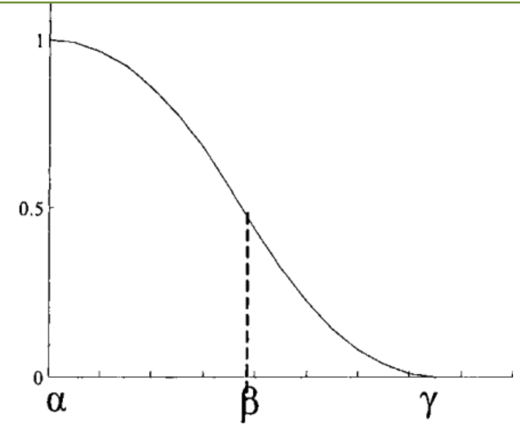
$$\mu_{Ld} = \begin{cases} 1, & \Delta < \alpha \\ 1-\frac{\Delta-\alpha}{b-\alpha}, \alpha \leq \Delta < \beta \\ 0, \Delta \geq \beta \end{cases}$$



Şəkil 7. Bounded decreasing linear membership function

S-shaped monotonically decreasing sigmoidal function

$$\mu_{Sd} = \begin{cases} 1, & \Delta \leq a \\ 1-\frac{1}{2}(\frac{\Delta-\alpha}{\gamma-\alpha})^2, \alpha \leq \Delta < \beta \\ \frac{1}{2}(\frac{\alpha-\Delta}{\gamma-\alpha})^2, \beta \leq \Delta < \gamma \\ 0, \Delta \geq \gamma \end{cases}$$



Şəkil 8. Monotonically decreasing sigmoidal membership function.

From these and other affiliate functions, new affliation functions can be created if necessary.

It is known that fuzzy estimation of other selected parameters or calculated parameters can also be performed, and in practice this is happening. Here we will define the rules for estimating the operating modes of the well for the three parameters selected. These rules use the values of the above smooth membership functions.

Rule 1: $If\ (\mu_{Gaussian}\ (d) \geq 0.7)\ and\ (\mu_{Si}(f) \geq 0.7)\ and\ (\mu_{Sd}(\Delta) < 0.2)\ then$
$well\ equipment\ \&\ rejimes\ searched\ exellent;$
Rule 2: $If\ (\mu_{Gaussian}\ (d) \geq 0.5)\ and(\mu_{Gaussian}\ (d) < 0.7)\ \ and\ (\mu_{Si}(f) \geq 0.7)\ and\ (\mu_{Sd}(\Delta) < 0.2)\ then$
$well\ equipment\ \&\ rejimes\ searched\ good;$
Rule 3: $If\ (\mu_{Gaussian}\ (d) \geq 0.7)\ and\ (\mu_{Si}(f) \geq 0.5)\ and(\mu_{Si}(f) < 0.7)\ \ and\ (\mu_{Sd}(\Delta) < 0.2)\ then$
$well\ equipment\ \&\ rejimes\ searched\ well;$
Rule 4: $If\ (\mu_{Gaussian}\ (d) \geq 0.5)\ and(\mu_{Gaussian}\ (d) < 0.7)\ \ and\ (\mu_{Si}(f) \geq 0.5)\ and$
$(\mu_{Si}(f) < 0.7)\ \ \ and\ (\mu_{Sd}(\Delta) < 0.2)\ then$
$well\ equipment\ \&\ rejimes\ searched\ poor;$
Rule 5: $If\ (\mu_{Gaussian}\ (d) \geq 50)\ and(\mu_{Gaussian}\ (d) < 70)\ \ and\ (\mu_{Si}(f) \geq 50)\ and$
$(\mu_{Si}(f) < 0.7)\ \ \ and\ (\mu_{Sd}(\Delta) \geq 0.6)\ then$
$well\ equipment\ \&\ rejimes\ searched\ not\ satisfied;$

It is obvious that it is possible to increase the number of rules. However, these rules are enough to show the solution.

5. Result

The article presents some methods for solving the problem of evaluating the selection of equipment and operating modes of oil wells with rod and depth pump. In order to solve these problems, a method of identification of dynamograms with the establishment of the distribution function of dynamograms and the application of the distribution function and a fuzzy method of selection of operating modes have been given. The experimental distribution function of dynamograms can be constructed from the values of the hanging force obtained by one method over one or more periods. The method developed in this sense does not depend on the choice of primary dymamometer converters and can be performed on any computer.

During the fuzzy evaluation of the selection of well equipment and modes, the parameter of pumping depth, filling percentage and proximity to the informational characteristics of the well dynamos selected from the current dynamograms as the normal reference were used. Various matching functions were selected as belonging functions.

Software experiments based on real and reference well dynamograms from mines demonstrate the effectiveness of generated methods and algorithms.

Ədəbiyyat

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