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THE FUZZY PROBLEM OF OPTIMAL DISTRIBUTION OF PASSAGES ALONG THE DEPTH OF THE WELL

Annotation: The problem of optimal distribution of passages along the depth of the well is considered. As the criterion of optimality the cost of drilling of the given interval is chosen. Taking into account that a number of parameters included in the optimality criterion can be estimated only approximate, such values are considered as fuzzy numbers. The last assumption made it possible to transform the deterministic problem of nonlinear programming into the problem of fuzzy nonlinear programming.

Keywords: optimization, criterion, distribution of passages, membership functions, fuzzy numbers.

The problem of optimal distribution of passages along the depth of the well, where the criterion of optimality is the cost of the drilled interval, was solved in the task [1] in a deterministic setting. Taking into account that the parameters of the optimality criterion cannot be precisely defined, they are interpreted as fuzzy values.

Therefore, the purpose of the work is to develop a method for optimal distribution of passages along the depth of the well in conditions of uncertainty.

[1] Proceeding from the mathematical model of the oil and gas wells deepening process, the following optimality criterion is obtained:

$$R(\bar{h}) = \sum_{i=1}^{N} \left(\frac{C_{б,i}}{K_{e,i}} e^{a_i h_i} + q_i h_i \right), \tag{1}$$

where $C_{б,i}$ – the value of the drilling unit's operation per unit time; $K_{ε,i}$ – the rate of change of the bit state in the ith run; $a_i = K_{e,i} / v_{0,i}$; $v_{0,i}$ – an average speed of the passage in the ith run; $q_i = \frac{C_{б,i}}{v_c} + \frac{1}{v_{cn}} \sum_{k=i+1}^{N} C_{б,\mathrm{k}}$; $v_{cn} = \frac{v_n v_c}{v_n + v_c}$; v_n, v_c- average speed of lifting and descent of the drilling instrument; h_i – value of the passage in the ith run; N – total number of runs.

The following values $C_{б,i}$, K_{ei}, $v_{0,i}$, v_n i v_c, which are included in the optimality criterion (1) can be determined only approximately by the results of drilled wells in similar geological and technical conditions.

Therefore, the values of the listed quantities will be considered as a fuzzy numbers with a triangular membership functions, which will be approximated by the exponential function

$$m(z) = \exp\left(-\frac{(z - z_0)^2}{2s^2} \right), \tag{2}$$

where z_0 – modal value of the fuzzy quantity z.

The parameter σ^2, which is a fuzzy parameter, is chosen so that the membership function (2) passes through a point $(z_A; 1/2)$, with coordinates belonging to the triangular membership function. The last condition has made it possible to determine the following

$$s^2 = \frac{\Delta^2}{32 \cdot \ln 2}, \tag{3}$$

where Δ – the basis of the triangular membership function.

Consequently, the values which are contained in criterion (1) will be interpreted as fuzzy numbers of $(L - R)$ type with membership functions (2) where $z \in \{C_{бi}, v_{0i}, K_{ε,i}\, v_c, v_n\}$. Modal value of the optimality criterion [2] was determined, after performing operations (adding, multiplying, dividing fuzzy numbers, multiplying the fuzzy number by a clear, and dividing a distinct number in the fuzzy) with fuzzy numbers

$$R_0\left(\bar{h}\right)=\sum_{i=1}^{N}\left(\frac{C_{б,i}^{(0)}}{K_{e,i}^{(0)}}e^{a_i^{(0)}h_i}+q_i^{(0)}h_i\right) \tag{4}$$

and the value of the fuzziness parameter of the optimality criterion (1)

$$s_R=\sum_{i=1}^{N}\left(a_{1,i}\left(h_i\right)+a_{2,i}h_i\right), \tag{5}$$

where $a_{1,i}\left(h_i\right)=\frac{e^{a_i^{(0)}h_i}}{K_{e,i}^{(0)}}\left(\frac{C_{б,i}^{(0)}}{K_{e,i}^{(0)}}a_{K_{e,i}}+a_{C_{б,i}}\right)$; $a_i^{(0)}=\frac{K_{e,i}^{(0)}}{v_{0,i}^{(0)}}$, $a_{a,i}=\frac{K_{e,i}^{(0)}a_{v_{0,i}}+v_{0,i}^{(0)}a_{K_{e,i}}}{\left(v_{0,i}^{(0)}\right)^2}$.

$a_{2,i}=\frac{C_{б,i}^{(0)}}{K_{e,i}^{(0)}}a_{a,i}e^{a_i^{(0)}h_i}+\quad+\frac{C_{б,i}^{(0)}a_{v_c}+v_c^{(0)}a_{C_{б,i}}}{\left(v_c^{(0)}\right)^2}+\sum_{k=i+1}^{N}\left(C_{б,k}^{(0)}\left(\frac{a_{v_c}}{\left(v_c^{(0)}\right)^2}+\frac{a_{v_n}}{\left(v_n^{(0)}\right)^2}\right)+\frac{a_{C_{б,k}}}{v_{cn}^{(0)}}\right)$; the upper index «0» indicates the modal values of the corresponding fuzzy numbers.

If $\gamma -$ cut is determined for the membership function, then the following is obtained

$$\tilde{R}\left(\bar{h}\right)=\sum_{i=1}^{N}\left(\frac{C_{б,i}^{(0)}}{K_{e,i}^{(0)}}e^{a_i^{(0)}h_i}+q_i^{(0)}h_i\right)+s_R\left(\bar{h}\right)\sqrt{\ln\frac{1}{g^2}}\ . \tag{6}$$

Now, the problem of optimal distribution of passage along the depth of the well will be formulated as the minimization of the optimality criterion (6) under the following restrictions:

$$0\le h_i\le h_{i,\max},\ i=\overline{1,N}, \tag{7}$$

$$\sum_{i=1}^{N}h_i=H, \tag{8}$$

where H - is the value of the drilled interval with N bits.

The problem (6) – (8) is reviewed in 3 cases: outgoing wear and tear, outgoing wear and tear of chisel and boring by blunt bit.

The number of bits that need to be spent to drill an interval in size H, which is usually limited to relatively small positive numbers, so the optimal selection N can be determined by a discrete search. For each value $N=2,3,\mathbf{K}$ the problem (6) is solved with restrictions (7) and (8). The optimal N^* number of coils corresponds to the smallest value of the optimality criterion (6).

References

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