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Yuxue Wang

Kaoping Song

Xian He

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Yuxue Wang
Address: Mathematical Science Department, Daqing Petroleum Institute, 151400 Anda, HeiLongJiang, China
Kaoping Song
Address: Petroleum Engineering Department, Daqing Petro leum Institute, 151400 Anda, HeiLongJiang, China
Telephone: 86-459-4654630
E-mail: skp@dqpi.edu.cn
Xian He
Address: Dagang Oilfield, Tianjin, China

ABSTRACT

In this paper, multi-objective programming is applied to solve the problem of multi-objective optimization in the field of drilling engineering. Mathematical model is established and practical run is conducted for a specific example.

INTRODUCTION

Drilling optimization is a job consisting of minimum cost and other indexes such as velocity and footage. Traditional single objective programming takes other indexes as constraints. This always deviates from objective facts and makes the problem no feasible solution. The multi-objective programming method is an effective way to optimize multi-objective problems. It adopts some special expression ways such as "soft constraints" and "preemptive priority" to successfully overcome the limitation of the single objective programming method.

BRIEF INTRODUCTION OF MULTI-OBJECTIVE PROGRAMMING[1][4][5]

Let controlled variable as $\vec{x}$, objective function as $f_i(\vec{x}), i = 1,2,\cdots,m$, the required object consists of $f_i(\vec{x}) \geq (\leq or =) b_i$. Adhibiting positive deviation variable p_i and negative deviation variable n_i, then

$$f_i(\vec{x}) + n_i - p_i = b_i \qquad i = 1,2,\cdots,n$$

If required object is $f_i(\vec{x}) \geq b_i$, then minimized n_i is needed only.

If required object is $f_i(\vec{x}) \leq b_i$, then minimized p_i is needed only.

If required object is $f_i(\vec{x}) = b_i$, then minimized $n_i + p_i$ is needed only.

Gift every objective function with prior progression, place the demanded minimum deviation variable of the highest priority at the first heft position of the vector. The general form of the mathematic model of the multi-objective programming problems is expressed as

$$\min \ \vec{a} = \{g_1(\vec{n},\vec{p}), g_2(\vec{n},\vec{p}),\cdots, g_k(\vec{n},\vec{p})\}$$

$$f_i(\vec{x}) + n_i - p_i = b_i \qquad i = 1,2,\cdots,m$$

Where

$$\vec{n} = (n_1, n_2, \cdots, n_m)$$

$$\vec{p} = (p_1, p_2, \cdots, p_m)$$

MULTI-OBJECTIVE PROGRAMMING PROBLEMS IN DRILLING TECHNIQUE[2][3][4][5]

The designers must seek for the best scheme while drilling construction as a serial of factors such as geology, equipment and technique are limited. Each well has its own actual situation and special demand, and the emergent degree among all the requests isn't equal, there hasn't identical measurement in compare with each other. It indicates the application of the multi-objective programming in drilling through an actual problem below.

The footage now of a well while drilling is 1,500m, the geology demand to sampling at the depth of 1,800m. In order to simplify the construction procedure, the production decision makers hope to reach the sampling horizon using only one bit under the premises of security and quality, at the same time they hope that the drilling cost and the ROP reach to the best level. Now the minimum direct drilling cost of the adjacent well is known as ¥80 per meter, the highest ROP is 9m per hour, the decision maker demand the designer to supply a group of technical proposal satisfied desire above.

Establishment Of Optimum Object

First: security production
Second: drilling 300m by one bit
Third: the direct drilling cost lower then ¥80 per meter
Fourth: the ROP higher than 9m per hour.

Selection Of Controllable Variable

Select the chief controllable parameter, which influence the drilling index directly as variables listed as follows:

K_b —— bit type(plastic variable)
W —— WOB, ton
N —— rotary speed, rpm
P_s —— stand pipe weight, kg/cm^2
Q —— flow rate, l/s

Establishment Of Constrains Condition

(1) WOB

The WOB shouldn't less than the volume breakdown pressure of formation drilling (5 ton) and higher than the highest pressure (25 ton) that bit can endure.

$$W + d^-_1 - d^+_1 = 5 \quad (1)$$

$$W + d^-_2 - d^+_2 = 25 \quad (2)$$

(2) Rotary Speed

The rotary speed shouldn't less than the minimum well drilling restricting rate (55rpm) and higher than the highest rate (150rpm) that bit can afford.

$$N + d^-_3 - d^+_3 = 55 \quad (3)$$

$$N + d^-_4 - d^+_4 = 150 \quad (4)$$

(3) Stand pipe weight

The stand pipe weight shouldn't less than the lower limit pressure ($130kg/cm^2$) that jet drilling requires and higher than the upper limit pressure ($220kg/cm^2$) that circulation system permits.

$$p_s + d^-_5 - d^+_5 = 130 \quad (5)$$

$$p_s + d^-_6 - d^+_6 = 220 \quad (6)$$

(4) Flow rate

The flow rate shouldn't less than the lowest flow rate (15 l/s) for carrying cuttings and higher than the largest flow rate (40 l/s) of mud pump liner.

$$Q + d^-_7 - d^+_7 = 15 \quad (7)$$

$$Q + d^-_8 - d^+_8 = 40 \quad (8)$$

(5) Constraint of bit bearing load

$$W \cdot N - B_n + d^-_9 - d^+_9 = 0 \quad (9)$$

(6) Constraint of pump horsepower

$$P_s \cdot Q - N_s \cdot 7.5 \cdot \eta + d^-_{10} - d^+_{10} = 0 \quad (10)$$

Where N_s is horsepower rating of mud pump and η is pump efficiency.

(7) Constraint of bit life

$$T(W, N) - 15 \cdot C_t + d^-_{11} - d^+_{11} = 0 \quad (11)$$

$$T(W, N) - 30 \cdot C_t + d^-_{12} - d^+_{12} = 0 \quad (12)$$

Where C_t is friction loss coefficient of bit cone.

(8) Constraint of drilling speed

$$\frac{91673.3Q}{D_h^2} - V(W, N, P_s, Q) + d^-_{13} - d^+_{13} = 0 \quad (13)$$

Where $V(W, N, P_s, Q) = KW^A N^B N_d^c e^{-E\Delta P}$.

(9) Constraint of bottomhole energy equilibrium

$$N_d - N_{cr} + d^-_{14} - d^+_{14} = 0 \quad (14)$$

Where $N_d = (p_s \cdot Q - K_c Q^{2.8})/(7.5A_b)$ and N_{cr} is the minimum specific hydraulic horsepower.

(10) Direct drilling cost

$$C(W, N, P_s, Q) - d^-_{15} - d^+_{15} = 80 \quad (15)$$

(11) Footage constraint

$$F(W, N, Ps, Q) + d^-_{16} - d^+_{16} = 300 \quad (16)$$

(12) ROP (rate of penetration)

ROP should be higher than 9m/h.

$$V(W, N, p_s, Q) + d^-_{17} - d^+_{17} = 9 \quad (17)$$

Where d_i^- and d_i^+ are deviation variables and $d_i^-, d_i^+ \geq 0$.

According to the requires of objective programming mathematical model, The objective function with minimum deviation variable can be described as

$$\min \vec{a} = \{d_1^- + d_2^+ + d_3^- + d_4^+ + d_5^- + d_6^+ + d_7^- + d_8^+ + d_9^{+-} + d_{10}^+ + d_{11}^- + d_{12}^+ + d_{13}^- + d_{14}^-, d_{16}^- + d_{16}^+, d_{15}^+, d_{17}^-\}$$

Then we obtain the optimal project as follows

Bits type	WOB (ton)	Rotary Speed (rpm)	Stand pipe weight (kg/cm^2)	Flow Rate (l/s)	Bit footage (m)	Drilling Cost (¥/m)	ROP (m/h)
J22	20.8	90	142	15.5	300	85	9.3

In this project, J22 bit is selected and footage is 300m. Direct drilling cost is higher than desired object slightly and ROP is higher than desired object. The optimal project meets well to the decision-maker's desire. And we will not obtain the feasible solution to this question if we adopt single-objective optimal method.

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REFERENCES

[1] Misa, S. and Skalle, P.: Theoretical Description of a new Method of Optimal Program Design.
SPEJ, (Aug. 1981), 425.

[2] Auen, J.H., Computer Optimizes Operations. OGJ, (Oct., 10, 1977)

[3] Luhandjula M.K., On Possibilitic linear programming, Fuzzy Sets and Systems, Vol.18 (1986), 15-30

[4] Liu B., Uncertain Programming,(John Wiley & Sons, New York,1999).

[5] Liu B., Dependent-chance programming in fuzzy environments, Fuzzy Sets and Systems, Vol.109 (2000), No.1, 95-104