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Optimization design of drilling string by screw coal miner based on ant colony algorithm*

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Abstract It took that the weight minimum and drive efficiency maximal were as double optimizing target, the optimization model had built the drilling string, and the optimization solution was used of the ant colony algorithm to find in progress. Adopted a two-layer search of the continuous space ant colony algorithm with overlapping or variation global ant search operation strategy and conjugated gradient partial ant search operation strategy. The experiment indicates that the spiral drill weight reduces 16.77% and transports the efficiency enhance 7.05% through the optimization design, the ant colony algorithm application on the spiral drill optimized design has provided the basis for the system research screw coal mine machine.

Keywords screw coal miner, optimization design, ant colony algorithm, two-layer search

Introduction

The screw coal miner principle of work is as the spiral conveyer, it has the truncation cutter tooth drill bit on helix arrangement in front part, it is one kind of new thin coal mining equipment[1-2]. As a result of the screw coal miner use environment particularity, such as coal or rock characteristic. Complexity[3-4], it frequently appears the phenomenon of the transportation card coal and falls the drill in the use process[5-6].

Optimizing choice basic parameter of the screw coal miner to suit different environment for using and working property requirement particularly important in the course of designing. The screw coal miner design criteria are enough. Intensity and rigidity and convey amount as the same time consume the little motive force. The drilling string is core of the screw coal miner, there are more parameters to influence designing. In the paper, it used optimizes the design theory to design the drilling string and used the continuous ant colony algorithm to find calculation answer.

1 Optimization design model

1.1 Designing requirement

It designs a kind of screw coal miner, the drilling string structure of screw coal miner is as shown in Fig.1, one hand in order to save materials and lower costs, another in order to improve drive efficiency.

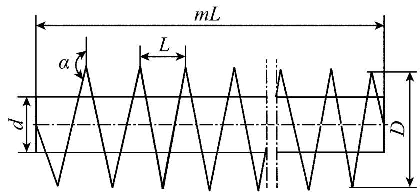

Fig.1 The drilling string structure of screw coal miner

(1) The drilling string drive efficiency calculate:

$$Q=\frac{\pi}{4}(D^2-d^2)L\cos\alpha-m\delta nk_c\frac{\cos(\alpha+\phi)}{\cos\phi}, \quad (1)$$

where, D is the blade maximum diameter, mm; d is the drilling string diameter, mm; L is the helix blade helical pitch, mm; α is the helix angle, (°); m is the blade quantity; δ is the blade thickness, mm; n is the helix drilling string rotation rate, r/min.

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(2) The drilling string quality calculate:

$$m=\rho\left[\frac{\pi d^2}{4}L(m-1)+\frac{(D-d)\delta L(\sqrt{\pi^2 d^2+L^2}+\sqrt{\pi^2 D^2+L^2})}{4L}\right]. \tag{2}$$

1.2 Design the variable

We can know from Eqs.(1) and (2), influence the drilling string parameter of L, n, α, δ, D, d, m, amount to 7 uncertain factors by formulae, while carrying on optimization design, regard it as the variable of design, so optimization variable of design $\boldsymbol{X}$ can be expressed as:

$$\boldsymbol{X}=[L\ n\ \ \alpha\ \delta\ \ D\ \ d\ \ m]^{\mathrm{T}}=[x_1\ \ x_2\ \ x_3\ \ x_4\ \ x_5\ \ x_6\ \ x_7]^{\mathrm{T}}.$$

1.3 Goal function

The drilling string minimum quality m is x function, obtain the equivalent goal function:

$$\min[F_1(x)]=\rho\left[\frac{\pi d^2}{4}L(m-1)+\frac{(D-d)\delta L(\sqrt{\pi^2 d^2+L^2}+\sqrt{\pi^2 D^2+L^2})}{4L}\right].$$

The drilling string of screw coal miner drive efficiency Q is x function, obtain the equivalent goal function:

$$\min[-F_2(x)]=-\frac{\pi}{4}(D^2-d^2)L\cos\alpha+m\delta nk_{\mathrm{c}}\frac{\cos(\alpha+\phi)}{\cos\phi}.$$

1.4 Restrain the condition

(1) Rigidity restrain. The screw coal miner max deflection should not exceed permission:

$$f_{\max}\le[f],$$

$$f_{\max}=k_1\frac{q(mL)^4}{16E\pi\left(D^4-d^4\right)/64}=0.052\times\frac{9.8(mL)^4}{16\times2\times10^{11}\times\pi\left(D^4-d^4\right)/64},$$

$$[f]\le 0.000\ 1\ mL.$$

(2) Power restrain. The screw coal miner power under load the condition should not exceed the electrical motor shaft power:

$$N\le N_0,$$

$$N=\frac{KQf_1L}{360D}\left[8mL\left(f_1+\frac{L}{D}\right)+\frac{30H_1L_1}{D}\right]=\frac{1.2\times0.35QL}{360D}\left[8mL\left(0.35+\frac{L}{D}\right)+\frac{30\times0.3\times0.5}{D}\right],$$

where, N_0 is the electrical motor shaft power.

(3) The rotational speed restrains. Spiral cylinder can put working into coal, spiral cylinder guarantee entering smoothly conveyer in the course of putting the coal, the working rotational speed must meet the relational expression:

$$n_1\le n\le n_2,$$

$$n_1=\frac{4Bv_{\mathrm{q}}(HK_{\mathrm{P}}K_1-H_0)\cos\beta}{\delta\left(D^2+d^2\right)\left(L\cos\alpha-m\delta\right)\Psi\cos\left(\alpha+\beta\right)}=\frac{4Bv_{\mathrm{q}}(1.6HK_1-H_0)\cos\beta}{\delta\left(D^2+d^2\right)\left(L\cos\alpha-m\delta\right)\Psi\cos\left(\alpha+\beta\right)},$$

$$n_2=\frac{(a+b)\sqrt{g}\cos\beta}{L\cos(\alpha+\beta)\cos\alpha\sqrt{2H-2h-D}}.$$

(4) The torsion intensity restrains. The max shearing stress of the empty mandrel screw coal miner should not exceed the terminal stress of the material:

$$\tau_{\max}\le[\tau],[\tau]=8\times10^7,$$

$$\tau_{\max}=\frac{T}{W_{\mathrm{n}}}=\frac{9.55\times10^6}{\frac{\pi}{16}D^3\left[1-\left(\frac{d}{D}\right)^4\right]}.$$

(5) The blade thickness restrains. The blade thickness value of border according to the intensity designed:

$$\delta_{\min}\le\delta\le\delta_{\max}.$$

(6) The internal diameter of the blade restrains. In order to guarantee the blade has enough loading the coal space, prevent stopping up or too much circulation coal amount, should keep certain proportion of the diameter D and internal diameter of the blade d.

$$0.3D\le d\le 0.4D.$$

(7) The helix blade promotes the restraint condition of the angle: helix blade angle is one of influence containing coal factor, its range:

$$23°\le\alpha\le35°.$$

(8) Helix blade helical pitch restrains. The two blades interval between should be approximate:

$$L\cos\alpha/m\ge400.$$

1.5 Mathematical model

$$\min[F_1(x)],$$

$$g_1(x)=f_{\max}-0.000\ 1mL\le0,$$

$$g_2(x)=N-N_0\le0,$$

$$g_3(x)=n_1-n\le0,$$

$$g_4(x)=n-n_2\le0,$$

$$g_5(x)=\tau_{\max}-[\tau]\le0,$$

$$g_6(x)=\delta_{\min}-\delta\le0,$$

$$g_7(x)=\delta-\delta_{\max}\le0,$$

$$g_8(x) = 0.3D - d \le 0,$$
$$g_9(x) = d - 0.4D \le 0,$$
$$g_{10}(x) = 23^\circ - \alpha \le 0,$$
$$g_{11}(x) = \alpha - 35^\circ \le 0,$$
$$g_{12}(x) = 400 - L\cos\alpha/m \le 0.$$

2 Ant colony algorithm and optimize calculate

2.1 The principle of ant colony algorithm

(1) Initialize the population. Produce N answers at random in the independent variable define-area to built the population, calculate adaptation degree of every individual, and arrange order according to the size, give the same pheromone initial value to them. Produce M ants, among them include G overall ants, L some ants.

(2) Overall search. Seek overall ants to operate exploring. Through cross and variation operating, produce new G ants to replace present population G ants.

(3) Some search. Seek some ant to operate excavating one by one, calculate N individuals to be chosen probability $P_i(x)$, choose L individual as the goal, optimize and search for the goal individual choosing them, lead individuals to the more excellent position.

(4) Pheromone is evaporated. Carry out pheromone to volatilize after changing and taking.

(5) Check the condition of stopping. Finish one search, population is checked to satisfied with terms of disappearing. If it is satisfied, export and solve optimumly at present; otherwise transfer to the step(2), the next is searched, until disappearing or meeting the request of scheduling.

2.2 Instance analysis

According to algorithm described above, optimize and ask solving. The parameter is established: Most different long λ corresponding half step by step, the overall situation search for step count k=40, utilize Matlab7.0 software to establish algorithm procedure calculating (Table 1). The experiment indicated that the spiral drill weight reduced 16.77% and transported the efficiency enhance 7.05% through the optimization design.

Table 1 Optimizes the results and compares

Project	X_1(mm)	X_2(r/min)	X_3(°)	X_4(m)	X_5(m)	X_6(m)	X_7	$F(x)$(kg)	η(%)
Routine designed	0.28	55~60	15	0.050	0.57	0.42	5	134.68	44.21
Optimization design	0.24	62.5	16.8	0.032	0.48	0.32	5	115.34	51.26

3 Conclusions

It take that the weight minimum and drive efficiency maximal are as double optimizing target, the optimization model has built the drilling string, and the optimization solution be used of the ant colony algorithm to find in progress. The experiment indicated that the spiral drill weight reduced 16.77% and transported the efficiency enhance 7.05% through the optimization design. The ant colony algorithm overcoming the regular design method the complicated and tedious shortcoming, the ant colony algorithm application on the spiral drill optimized design has provided the basis for the system research screw coal mine machine.

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