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Research on Hydraulic Control System of Jumbolter Based on Intelligent Mix Optimization Algorithm

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Abstract

This paper found the deficiency of classical Z-N method in optimization of PID parameters, proposed the intelligent optimization algorithm of PID parameters .The stimulation and experiment showed that the PID parameters getting from this algorithm are efficient, accurate and speedy. This paper used algorithm for hydraulic control system of jumbolter. The stimulation and experiment showed that when peak oil pressure of relief chamber is changed, optimum algorithm will find suitable and based on MAX power requirement to change displacement of relief surface, which lead to changing displacement of impact piston, at the same time, it will change the impact power and frequency of impactor, and realize impactor auto change working parameters based on the different situation under suitable parameters and MAX power working condition. The experiments show that it has a certain reference value for other control objects and control process.

Keywords*: Intelligent optimization algorithm; Control strategy; Variable stroke adjusting mechanism; Performance Matching*

1. Introduction

Jumbolter is the key equipment of anchor bolt support construction, in recent years, with the rapid development of geotechnical engineering in our country, the airborne rotary hydraulic jumbolter has widely and commonly used in coal roadway tunnels and geotechnical anchoring engineering construction. The hydraulic control system of onboard rotary type jumbolter adopts traditional Z-N [1] setting PID (proportional integral differential) controller parameters. Ziegler-Nichols method is simple and practicable, but parameters need to be further adjusted. In recent years, it develops the genetic algorithm (GA) [2] optimization method and ant colony algorithm optimization method, *etc*. [3].These algorithms compared with the classical Z-N method, PID parameter optimization performance is somewhat improved, but there are also some problems, such as easy to premature convergence, easy to appear stagnation phenomenon, the global search ability is not high. Ant colony algorithm research mainly by experiment means to improve the convergence speed and stagnation phenomenon of the algorithm. In the published references[4], the author through the genetic algorithm to regard PID parameter initial value as an operating object, and then using the improved ant colony algorithm of adaptive adjustment path selection probability and pheromone update rules, and search out the optimum PID parameters in the end. Based on this, this paper proposes PID parameters setting method based on intelligence fusion of optimization algorithm, and applies this algorithm to hydraulic system control strategy research of jumbolter, the simulation and experiment show that under different conditions, jumbolter according to the changes of peak buffer chamber oil pressure of its variable travel agency, using intelligent optimization algorithm, automatically adjusts working parameters of equipment, ensure the drilling machine operating with maximum power under the

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reasonable parameter matching condition. The results verify the rationality and feasibility of the control strategy design of the onboard rotary jumbolter hydraulic system under the condition of the intelligent fusion optimization algorithm and setting PID parameters and the actual working condition, so as to improve work efficiency and reduce energy consumption [5].

2. Intelligence Fusion Optimization Algorithm Setting PID Parameter

PID proportional integral derivative controller, because of its simple algorithm, good robustness, high reliability, convenient adjustment, has become one of the major irreplaceable technologies in industrial process control and motion control. One setting PID controller parameter method that is commonly used in engineering is classic Z-N method. Ziegler-Nichols method is simple and practicable, but the parameters need to be further adjusted[1][4].

Based on this, this paper based on the algorithm proposed in reference[4], using intelligent fusion optimization algorithm setting the PID parameter, the basic idea of which is on the basis of classic Z-N method obtained initial value of PID parameter, through genetic algorithm (GA) to put the initial value of PID parameter as an operating object, and then use the improved ant colony algorithm of adaptive adjustment path selection probability and the pheromone update rules, and search out the optimum PID parameters in the end. Intelligent integration optimization algorithm process is shown in Figure 1[4].

2.1. Intelligence Fusion Optimization Algorithm setting PID Parameter Steps

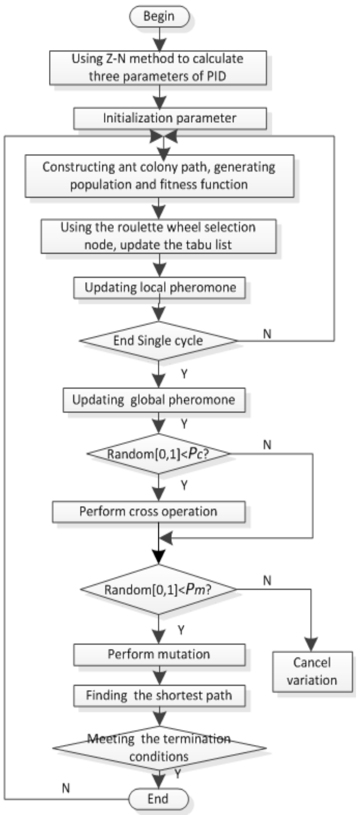

Figure 1. Intelligent Integration Optimization Algorithm Flow Chart

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2.2. Simulated Analysis

Assumed the transfer function of onboard jumbolter hydraulic impact rotary electro-hydraulic servo system is $G(s) = 5268 / s(s^2 + 133s + 110889)$, then carries on simulation on the system transfer function by this algorithm.

Take the system input as unit step signal.

Let $0 \le \alpha < 5, 0 \le \beta < 5, 0.1 \le \rho < 0.99, 1 \le Q < 10000$ (where α 、 β 、 ρ and Q respectively are constants of information stimulating factor, expected inspired factor, pheromone volatilization factor, and the ant legacy track number), the ant number is 30; iteration number is 100. Parameter range of PID control system is; the range of K_p is [0.00001 20], the value range of K_i, K_d is [0.00001 2].

This paper fuses the performance of intelligent optimization algorithm, respectively compared with the performance of classic Z-N method, ant colony algorithm, and genetic algorithm, Figure 2 shows the corresponding PID unit step response of each algorithm, and Table 1 lists PID setting parameters and the system unit step performance index of each algorithm [4].

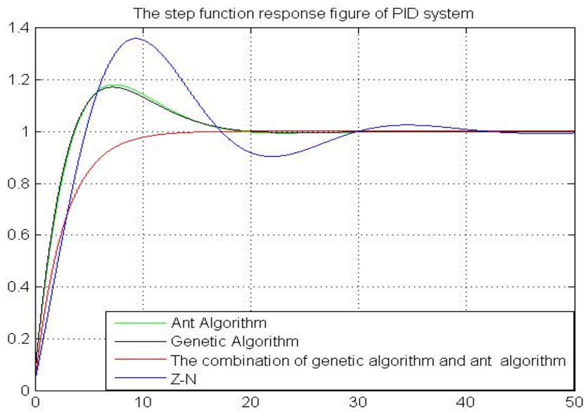

Figure 2. Algorithm Unit Step Responds Chart

Table 1. Comparison Table of System Unit Step Performance

ALGORITHM	K_p	K_i	K_d	t_s	e_{ss}	σ%
Z-N	4.58	1.6	0.8	37.35	8.2574e-8	35.9714
ACS	10.0	1.9944	1.6878	16.58	4.4409e-14	18.1963
GA	10.5228	1.9999	1.5159	16.72	3.3307e-14	17.
ACS-GA	8.0112	0.0071	0.6488	10.25	0.1676	0.1676

It can be seen from Table 1, compared with other control algorithms, the proposed intelligent fusion optimization algorithm setting of three parameters of PID – proportional coefficient *KP* , integral coefficient *Ki*, and differential coefficient *Kd*, are the optimal, and its unit step response performance, compared with other control methods, the parameter steady-state regulation error of reaction system stability performance is minimum, the parameter regulation time *ts* of reaction system dynamic-state response performance and overshootσ% are greatly reduced. It is demonstrated that the control

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effect of this algorithm is the best (minimum overshoot amount, shortest setting time), as a result, the algorithm has the optimal control performance and robustness [4].

The simulation results show that the algorithm can be find the optimal solution rapidly and effectively within the scope of the solution, so it is laid a solid theoretical basis for the algorithm as an optimization control strategy for an onboard jumbolter hydraulic control system [6].

3. Experimental Example

The key components of hydraulic mechanical impact onboard jumbolter are impact piston, flow-distribution control valve, accumulator and variable stroke regulating mechanism [6~9]. Its variable stroke regulating mechanism structure diagram is shown in Figure 3. The optimization goal is to ensure under the condition of maximum power N, the reasonable system working pressure Pd and propulsive force of feed mechanism Ft, the related mathematical model as shown in equation (1) and (2).

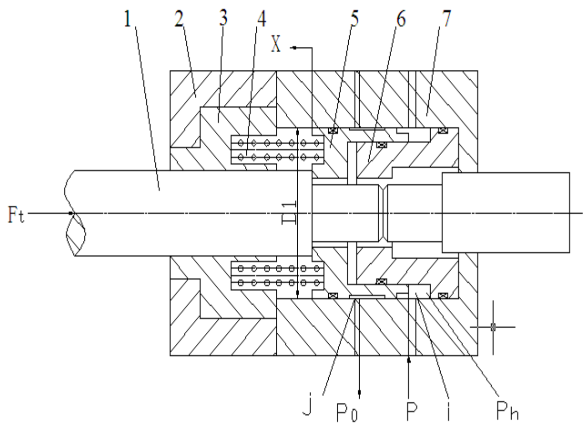

Figure 3. Variable Stroke Adjustment Mechanism Model

1-Drill Rod;	2-Organism;	3-Drill sleeve;
4- Regulating spring;	5-Buffer shell;	
6- Bufferinner;	7- Intermediate	

Working principle of the variable stroke regulating mechanism is: based on the peak oil pressure differential pressure changes of buffer chamber i, make dynamic matching of system working pressure Pd and propulsive force of feed mechanism Ft, so as to ensure the hydraulic shock operating in the optimal stroke scope, and the power of jumbolter is achieved the optimal working state[6~11].

3.1. Mathematical Model of Variable Stroke Regulating Mechanism

According to the Figure 3 and dynamic balance of moving body, it can set up a variable stroke regulating buffer jacket, the dynamics equation as follows[6~8]:

$$m\frac{d^2x}{dt^2} = F_P - F_k - F_t - F_B - F_f \tag{1}$$

$$F_p = AP_h, F_k = k(x + x_0), F_t = \frac{\pi}{4}P_t D_1^2 \tag{2}$$

where, m is the weight of buffer jacket, kg; X is the displacement of buffer jacket, m; Fp,Fk,Ft,FB,Ff respectively are oil pressure, spring force, propulsive force, viscous resistance and seal friction (ignored) N; Ph, Pt respectively are operating oil pressure of buffer chamber and hydraulic cylinder, MPa; A,K,x0 and D1 respectively are section area of buffer jacket, m2; regulating spring stiffness, N/m; regulating spring pre-compression, *m* and buffer chamber diameter, m.

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To simplify eqaution (1) and (2) (ignore the viscous resistance FB and seal friction Ff, and get [6] :

1) x Impact device moving body buffer jacket displacement x

$$x = 0.0311014P_d - 0.0646P_t - 0.002 \tag{3}$$

2) Impact device impact stroke

$$S_j = S_j{}' + \Delta S = S_{j0}{}' + x + x_0 \tag{4}$$

Where, Sj and Sj'respectively are piston return accelerated trip stroke and piston return reversing stroke, m; Sj0' represents fixed set minimum return reversing stroke of piston on impact device cylinder m; x and x0 respectively are buffer jacket displacement and regulating spring pre-compression m.

3.2. Objective Function

On the basis of considering various features of working device, in order to achieve the required maximum power in current condition, jumbolter impact energy optimal matching with impact frequency, to achieve the optimal drilling efficiency, taking system input oil pressure Pd and propulsive oil pressure Ft of impact device as the value to be optimized, and the maximum output power of the impact device N as objective function.

$$N = E \bullet f = 10^6 \frac{(1-\alpha)^2 A}{k(1-2\alpha)} \bullet P_d S_j \bullet 10^3 \frac{\alpha}{1-\alpha} \sqrt{\frac{A(1-2\alpha)}{2k^3 m}} \bullet \sqrt{\frac{P_d}{S_j}} \tag{5}$$

E and f respectively are impact energy and impact frequency; $\alpha = 0.29$ (abstract parameter)[8] [10~11]; according to the changes of buffer chamber peak oil pressure difference △Ph, using Intelligent fusion optimization algorithm to search suitable parameter values within Pd and Pd, ; Pt and Pt, scope, to ensure the parameters of this impact can maintain reasonable system operating oil pressure Pdand system propulsive oil pressure Pt at the maximum power N.

$$\begin{aligned} P_d' &= P_d + k_1 \Delta P_h \\ P_t' &= P_t - k_2 \Delta P_h \end{aligned} \tag{6}$$

In equation: Pd, and Pt, respectively are the system operating oil pressure and propulsive oil pressure limit value of optimization, Mpa; K1=0.3 (operating oil pressure correction coefficient); K2=0.1 (propulsive oil pressure correction coefficient); △Ph is the peak l oil pressure difference of buffer chamber with previous, Mpa.

parameter setting range of onboard jumbolter: Pt: 5~10Mpa; Pd:10~18Mpa; N:20000W; xscope: -0.020m~0.020m; Sj0:0.03m; x0: 0.002m.

3.3. Optimization Algorithm Result

Set previous impact parameter of impact device: ①Pd=14Mpa, Pt=7Mpa; ②Pd =15Mpa, Pt =7.8Mpa; ③Pd=17Mpa, Pt=78.6Mpa;. Peak oil pressure difference of buffer chamber △Ph respectively are -3Mpa; -2Mpa; -1Mpa; 1Mpa; 2Mpa; 3Mpa, substitute into the hybrid optimization algorithm to optimize, and get one and next (follow-up) operating parameter of impact device as shown in Table 2 ~ 3; Table 4 ~ 5.

Table 2. Initial Operating Parameters of an Impact Device

Working oil pressure P_d(Mpa)	Pushing oil pressure P_t(Mpa)	Impactin genergy E(J)	Impacting frequency f(Hz)	Impactin gpower N (kw)	Relief surface displacement x (m)	Impacting position distance S_j (m)
14	7	420	22.53	9.4636	0.00934	0.04134

Table 3. Next Impactor Operating Parameters Optimization Results

ΔP_h	-3	-2	-1	1	2	3
P_d'	13.489	13.655	13.869	14.267	14.498	14.688
P_t'	6.778	6.887	6.98	7.082	7.199	7.294
E	373.28	356.717	376.367	475.247	482.958	491.737
f	23.029	23.847	23.581	21.586	21.759	21.847
N	8.096	8.507	8.875	10.259	10.051	10.743
x	0.006	0.004	0.005	0.014	0.014	0.014
S_j	0.038	0.036	0.037	0.046	0.046	0.046

Table 4. Initial Operating Parameters of an Impact Device

Working oil pressure P_d(Mpa)	Pushing oil pressure P_t(Mpa)	Impacting energy E(J)	Impacting frequency f(Hz)	Impacting power N (kw)	Relief surface displacement x(m)	Impacting position distance S_j (m)
15	7.8	183	36.574	6.698	-0.0152	0.01684

Table 5. Initial Operating Parameters of an Impact Device

ΔP_h	-3	-2	-1	1	2	3
P_d'	14.2	14.9	14.95	15.28	15.52	15.85
P_t'	7.7206	7.805	7.920	7.832	7.884	8.012
E	123.66	131	130.19	292.13	365.43	410.245
f	42.119	42.945	43.217	29.493	26.786	25.811
N	5.208	5.625	8.847	8.614	9.786	10.589
x	-0.02 (-0.0395)	-0.0199	-0.02 (-0.0274)	-0.0057	0.0005	0.00367
S_j	0.012	0.012	0.012	0.0263	0.032	0.036

It can be seen from Table 2 to Table 5, when the impact device in the process of rotary propulsion, intelligent optimization algorithm can according to medium hardness changes, automatically regulate the impact energy and frequency of the impact device, namely when working medium is soft or has been broken, elasticity of drill rod is smaller, which leads to the decrease of the oil pressure in buffer chamber, ΔPh is smaller, then automatically regulates hydraulic cylinder propulsive oil pressure Pt and system operating oil pressure Pd, reduces the buffer displacement, and can increase the impact energy of the impact device, and decrease the corresponding impact frequency [6].

4. Conclusion

The PID parameters setting of intelligent fusion optimization algorithm proposed in this paper. The basic idea of it is on the basis of classic Z-N method to obtain PID parameter initial value, through genetic algorithm (GA) to put PID parameter initial value as an operating object, and then use the improved ant colony algorithm for adaptive adjustment path selection probability and pheromone update rules, ultimately search out

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the optimal PID parameters setting value. The simulation results show that the algorithm can find the optimal solution that meets the requirements rapidly within the scope of solution, the author applied this algorithm to onboard hydraulic system control strategy research of jumbolter. Through an engineering example, it realizes the principle of jumbolter changes over the operating object and the required power shall be maximum, combined with the changes of buffer chamber peak oil pressure ΔPh of variable stroke mechanism, using the intelligent fusion optimization algorithm, optimal matching the hydraulic cylinder propulsive force Ft and system operating oil pressure Pd, to make jumbolter to achieve the optimal working state by reasonably regulating the impact energy E and impact frequency f under the maximum power in current working situation, so as to verify the correctness and feasibility of the intelligent fusion optimization algorithm, and has certain reference values to other control objects and control processes.

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References

[1] Y.-H. Wang, "Modern electrical control and the Application of PLC Technology", BEIJINGuniversity Press, (**2008)**.
[2] W. K. Ho, C. C. Hang and L. S. Cao, "Tuning of PID controllers based on gain and phase margin Specifications", Automatica, vol. 31, no. 3, **(1995)**, pp. 497-502.
[3] P. Wang and D. P. Kwo, "Optimal Design of PID Process Controllers Based on Genetic Algorithms", Control Eng Prac, vol. 2, no. 4, **(1994)**, pp. 641-648.
[4] X. Wang, "Optimization Design Based onself-adapted Ant Colony and genetic fusion Algorithm for Parameters of PID Controller", International Journal of Hybrid Information Technology[J], vol.8, no.7, **(2015)**, pp. 411-422.
[5] X. Wang, "The transformation of Hydraulic Roofbolter frequency Control system based on PLC and hmi.machinetoolhydraulics", vol. 43, no. 10, (**2015)**, pp. 172-174.
[6] X. Wang, "The research control optimization strategy Based on fusion algorithm For hydraulic drive control System of jumbolter", Xi'an University of Architecture and Technology, **(2014)**.
[7] Z.ng Liu, "The Research Of Design The Oryand Control Strategy On The New Hydraulic Impact Machine", CentralSouthUniversity, **(2001)**.
[8] G.-P. Yang, "The research of a fully draulic pressure hydraulic impactor with strike energy and strike frequency and justed steeplessly", Central South University, vol. 12, **(2000)**.
[9] H.-Q. Li, "The research on impact mechanism and hydraulic drive system for Heavy hydraulic rock drill", Central South University, **(2010)**.
[10] L. He, "Research on Key Technologies of the New Full-hydraulic Multi-functional Roofbolter", China University of Geoscience, **(2010)**.
[11] Q.-H. He, "RESEARCHAND DESIGN OF HYDRAULIC IMPACT MECHANISM", Central South University Press, **(2010)**.

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