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Research Article

Study on the Control Method of Mine-Used Bolter Manipulator Based on Fractional Order Algorithm and Input Shaping Technology

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Mine-used bolter is the main equipment to solve the imbalance of excavation and anchor in well mining, and the manipulator is the main working mechanism of mine bolt drilling rig. The manipulator positioning requires high rapidity and stability. For this reason, this paper proposes a composite control method of "input shaping + fractional order PD^{μ} control". According to the mathematical model of the valve-controlled cylinder, the fractional-order controller PD^{μ} is developed. At the same time, the input shaping is used to feed forward the accurate positioning and path planning of the manipulator, which not only improves the robustness of the system, but also shortens the stability time of the system and restrains the maximum amplitude of the system vibration. In this paper, the control effects of fractional order PD^{μ} controller and integer order *PD* controller are compared. The results show that the maximum amplitude of the control system is reduced by 75% and the stabilization time is reduced by 60% after using the fractional order PD^{μ} controller, which fully reflects the superiority of the fractional order controller in response speed, adjusting time, and steady-state accuracy. Finally, the control effects of "input shaping + fractional order PD^{μ} control" and fractional order PD^{μ} controller on the stability of the system are compared. The maximum amplitude of the system was reduced by 50% by using "input shaping + fractional order PD^{μ} control". Numerical simulation confirms the feasibility and effectiveness of the composite control method. This composite control method provides theoretical support for the precise positioning of the manipulator, and the high stability and high safety of the manipulator also expand the application scope and depth of the composite control method.

1. Introduction

At present, underground mining areas mainly require excavation and support, but there is a serious imbalance between them. The artificial support time accounts for 2/3 of the mining time. In order to improve the supporting efficiency, a mine-used bolter is developed. A mine-used bolter consists of a chassis, a variable frequency electric traction fixed interval control system, an electric control system, two manipulators which have the function of leveling telescopic, two automatic drilling frames, a driving operation mechanism, fore and aft stabilizers, a roll-cable device, a spread roof mesh device, an auto spraying device, etc. The schematic diagrams of the mine-used bolter are shown in Figures 1 and 2. The manipulator is the main working mechanism of the device, consisting of 6 free joints. The position control performance of each joint is directly related to the support efficiency of the mine-used bolter, so controlling a mine-used bolter's manipulator has become the hotspot and difficulty of research.

Previously, a traditional *PID* control was used for the spatial position and attitude of the manipulator. In view of the obvious advantages of the *PID* controller [1–3], the preview following theory [4, 5] has achieved good results in traditional *PID* control. However, when the mine-used bolter works underground, the underground environment is harsh and the external load is prone to change, and the

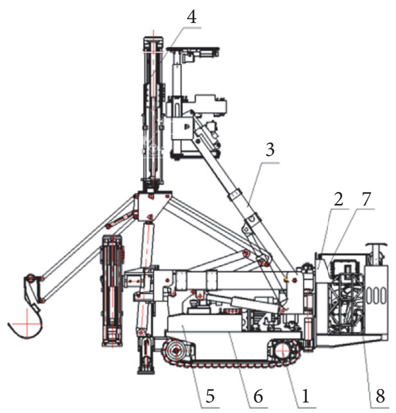

Figure 1: Schematic diagram I of mine-used bolter structure. 1: frequency control of motor speed walking mechanism, 2: electrical control system, 3: telescopic arm, 4: automatic drilling frame, 5: hydraulic system, 6: frame, 7: driving operation and monitor, and 8: directional cruise control and step measurement system.

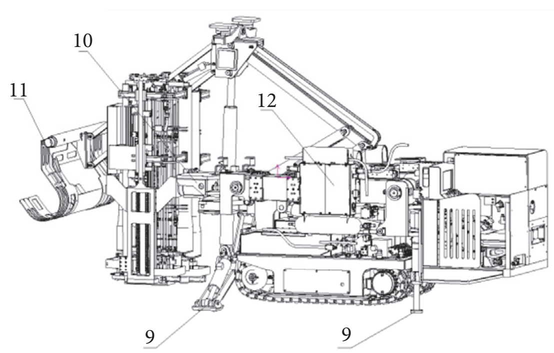

Figure 2: Schematic diagram II of mine-used bolter structure. 9: fore and aft stabilizer, 10: leveling mechanism, 11: spread roof mesh device, and 12: spraying volume box.

load will change with the different needs of the underground operators. Especially under special conditions, the control effect of traditional *PID* is unsatisfactory if the manipulator needs to achieve the goal of track tracking and spatial positioning quickly. At this time, the parameters of the *PID* need to be reset. Even after adjusting the parameters, the expected target value of the control effect of the mine-used bolter could not be reached by the integer order *PID* controller. In order to improve the control effect of integer order *PID* controller, the authors Ge LI, Wang Y F, and Liu Land so on in [6–16] used different *PID* algorithms in various control systems, such as integral separation *PID* control algorithm, fuzzy control *PID* control algorithm, neural network *PID* control algorithm, and so on. In essence, none of the above algorithms overcome the shortcomings of the traditional PID algorithm with relatively limited parameter range. According to the above discussion, a fractional order $\mathrm{PI}^{\lambda}\mathrm{D}^{\mu}$ controller with better dynamic and robustness must be developed to provide a greater guarantee for the spatial positioning of the manipulator of the mine anchor drill underground. Podlubny [17] first proposed the model of fractional order proportional-integral-differential controller. The basic knowledge of the definition, properties, Laplace transformation, and application of fractional order calculus is introduced in [18–22]. Compared with the integer *PID*, the expression of fractional $PI^{\lambda}D^{\mu}$ controller has two parameters λ, μ, which increases the adjustment range of parameters. It provides the theoretical basis and technical support for the formulation of fractional order proportional-integral-differential controller for the position and attitude of the manipulator of the mine-used bolter. References [23, 24] also put forward optimization methods for two parameters in fractional order $PI^{\lambda}D^{\mu}$ expression. The common optimization methods are combined with neural network, particle swarm optimization, and genetic algorithm based on finite difference to find the optimal parameters of λ, μ, which ensures the optimal control effect of fractional order $PI^{\lambda}D^{\mu}$ controller. However, all the above research work was based on the design and optimization of a single fractional order $PI^{\lambda}D^{\mu}$ controller and did not combine any kinds of feed-forward control-input shaping devices to form a composite controller to control the stability of the system together. In [25], a composite control method based on proportional-differential feedback and moment feed-forward was proposed to achieve the joint attitude of the mechanism. Similarly, a hybrid control method, which combined variable structure control and input shaping technology, was proposed in document [26] and applied to fast and agile maneuvering control of satellite attitude. The above two references [25, 26] showed that compound control could not only effectively improve the anti-jamming performance of the system, but also improve the speed of trajectory tracking. In view of the advantages of fractional order algorithm and composite control method, a composite control method combining fractional order PD^{μ} controller and input shaping technology is developed for the space trajectory tracking and precise positioning of the manipulator of mine-used bolter, which ensures that the manipulator can efficiently, safely, and steadily complete the trajectory tracking and positioning while working underground. The control block diagram is shown in Figure 3.

2. Mathematical Model of Electrohydraulic Proportional Control System for Manipulator

The rotation angle and displacement of each joint of the manipulator of the mine-used bolter are driven by the corresponding proportional valve and cylinder. In order to realize the trajectory tracking and precise positioning of the manipulator of the mine-used bolter, the electrohydraulic proportional position control system is adopted at each joint. Figure 4 is a block diagram of the transfer function of a position system for the electrohydraulic proportional control of a hydraulic cylinder with a valve controlled single pole. The transfer function of the hydraulic power system can be obtained from Figure 4.

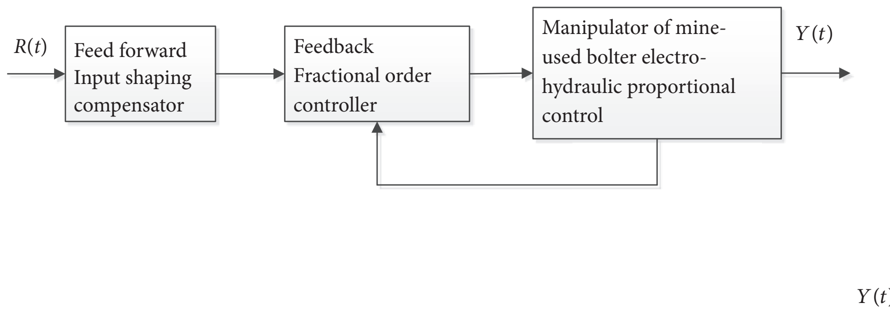

FIGURE 3: Schematic diagram of control system structure.

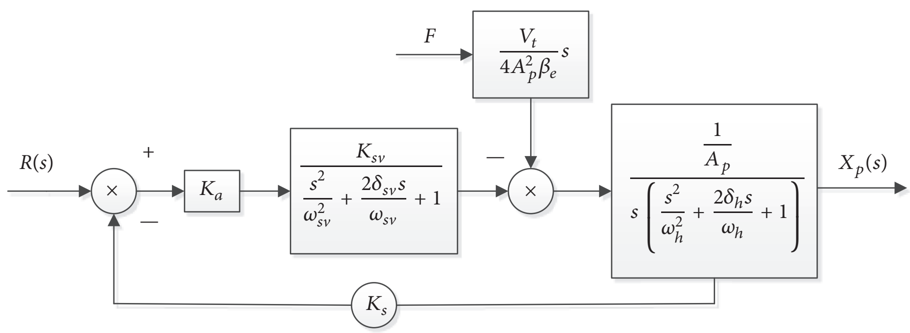

FIGURE 4: Block diagram of transfer function of location system.

TABLE 1: Parameters of valve controlled hydraulic cylinder.

Parameters of the symbol	Parameter name	Unit	Oil cylinder
L	trip	mm	1100
D	cylinder bore	mm	80
d	piston rod diameter	mm	45
ξ_h	hydraulic damping ratio	--	0.4
m_t	drive equivalent load	kg	2000
β_e	oil equivalent elastic modulus	Pa	$7.0*10^8$
c_ϖ	proportional valve core area gain	mm	18
Δp	proportional valve rated core inlet and outlet differential pressure	Mp	1.6
ρ	the oil density	kg/m^3	860

The external load is $F = 0$, $R(s)$ which is a reference input, and X_p is the transfer function of the output of the hydraulic cylinder. The process parameters are shown in Table 1. The relevant parameter values are subdivided into the above sections. In the case of neglecting the external load force, the open-loop transfer function of each joint position system of the manipulator can be solved, as shown in (1) formula.

$$\begin{aligned} G(s) &= \frac{k_q/A_p}{s\left(s^2/\omega_h^2 + (2\xi_h/\omega_h)s + 1\right)} \\ &= \frac{0.155/\left(3434\times 10^{-6}\right)}{s\left(s^2/20.9^2 + ((2\times 0.4)/20.9)s + 1\right)} \\ &= \frac{45.1}{s\left(s^2/436.81 + 0.04s + 1\right)}, \end{aligned} \quad (1)$$

where $\omega_h = \sqrt{4\beta_e A_p^2/V_t m_t}$ (ω_h is natural frequency of hydraulic cylinder, unit: rad/s), $\xi_h = 0.4$ (ξ_h is hydraulic damping ratio), A_p is effective working area of piston hydraulic cylinder (unit: m^2), and k_q is proportional valve flow gain.

3. Design of Fractional Order PD^μ Controller for the Manipulator of Mine-Used Bolter

The transfer function of fractional order $PI^\lambda D^\mu$ is as follows:

$$G(s) = K_p\left(1 + \frac{K_i}{s^\lambda} + K_d s^\mu\right) \quad (2)$$

When the parameters λ and μ are taken different values, the $PI^\lambda D^\mu$ controllers of different fractional stages can be obtained. The range of parameters is wider and the system regulation is more flexible.

The main design methods of $PI^{\lambda}D^{\mu}$ controller are dominant pole method [25, 26], optimization methods [27], and so on. In order to track and locate the space trajectory of the manipulator accurately, the fractional order $PI^{\lambda}D^{\mu}$ controller is designed by using the method of amplitude, phase margin, and robustness constraints.

3.1. Design of a Fractional Order PD^{μ} Controller. Eq. (2) indicates that the transfer function of the fractional order PD^{μ} controller is

$$C(s) = K_p(1 + K_d s^{\mu}), \quad (3)$$

K_p refers to a proportional constant, K_d refers to a differential constant, and u refers to the fractional order of the controller, $\mu \in (0, 1]$. The phase-frequency and amplitude characteristics of the valve-controlled oil cylinder for the manipulator are as follows:

$$\arg|G(j\omega)| = -\frac{\pi}{2} - \arctan\frac{(2\xi_h/\omega_h)\,\omega}{1-\omega^2/\omega_h^2}, \quad (4)$$

$$|G(j\omega)| = \frac{k_q/A}{\omega\sqrt{(1-\omega^2/\omega_h^2)^2 + ((2\xi_h/\omega_h)\,\omega)}}. \quad (5)$$

Eq. (3) of the PD^{μ} fractional order controller can be shown as Laplace transform as follows:

$$\begin{aligned} C(j\omega) &= K_p\left[K_d(j\omega)^{\mu}\right] \\ &= K_p\left(1 + K_d\omega^{\mu}\cos\frac{\mu\pi}{2} + jK_d\omega^{\mu}\sin\frac{\mu\pi}{2}\right). \end{aligned} \quad (6)$$

The phase-frequency and amplitude characteristics are

$$\begin{aligned} &\arg|C(j\omega)| \\ &\quad = \arctan\frac{\sin((1-\mu)\pi/2) + K_d\omega^{\mu}}{\cos((1-\mu)\pi/2)} - \frac{(1-\mu)\pi}{2}, \end{aligned} \quad (7)$$

$$\begin{aligned} &|C(j\omega)| \\ &\quad = K_p\sqrt{\left(1 - K_d\omega^{\mu}\cos\frac{\mu\pi}{2}\right)^2 + \left(K_d\omega^{\mu}\sin\frac{\mu\pi}{2}\right)^2}. \end{aligned} \quad (8)$$

The open-loop transfer function is

$$L(s) = C(s)\,G(s). \quad (9)$$

The phase characteristics of the open-loop transfer function can be obtained through (4) and (7) as follows:

$$\begin{aligned} \arg|L(j\omega)| &= \arctan\frac{\sin((1-\mu)\pi/2) + K_d\omega^{\mu}}{\cos((1-\mu)\pi/2)} \\ &\quad - \frac{(1-\mu)\pi}{2} - \frac{\pi}{2} - \arctan\frac{(2\xi_h/\omega_h)\,\omega}{1-\omega^2/\omega_h^2} \end{aligned} \quad (10)$$

The fractional order PD^{μ} controller is analyzed in frequency domain, which must satisfy three constraints. It can be derived from the basic definition of cut-off frequency, amplitude, and phase margin.

(1) Constraint of the Phase Margin

$$\arg|L(j\omega_{cg})| = \arg|C(j\omega_{cg})|\,|G(j\omega_{cg})| = -\pi + \varphi_m. \quad (11)$$

ϕ_m refers to the phase margin and ω_{cg} refers to the cut-off frequency. The phase margin can be regarded as a phase change that can be increased before the system enters a stable state. If the phase margin is large, then the system is stable. However, the time response speed decreases at the same time. Therefore, an appropriate phase margin must be selected based on different controlled objects.

(2) Robustness Constraint

$$\left.\frac{d(\arg[L(j\omega)])}{d\omega}\right|_{\omega=\omega_{cg}} = 0. \quad (12)$$

The derivative is obtained for the phase–frequency function of the open-loop system $L(j\omega)$ based on (12), and its zero point is fixed at the cut-off frequency. Thus, the phase becomes flat around the cut-off frequency ω_{cg}, and the closed-loop system is robust to changes in system gain. Even when the system gain is changed in a certain range, the system overshoot remains unchanged. This constraint condition is the core reason that the manipulator has good robustness.

(3) Constraint of the Amplitude Margin

$$|L(j\omega_{cg})| = |C(j\omega_{cg})|\,|G(j\omega_{cg})| = 1. \quad (13)$$

The parameters of the fractional order PD^{μ} controller can be obtained by the constraint of the amplitude margin.

$$\begin{aligned} \arg|L(j\omega)| &= \arctan\frac{\sin((1-\mu)\pi/2) + K_d\omega^{\mu}}{\cos((1-\mu)\pi/2)} \\ &\quad - \frac{(1-\mu)\pi}{2} - \frac{\pi}{2} - \arctan\frac{(2\xi_h/\omega_h)\,\omega}{1-\omega^2/\omega_h^2} \\ &= -\pi + \phi_m. \end{aligned} \quad (14)$$

The relationship between K_d and μ can be obtained using (14) as follows:

$$\begin{aligned} K_d &= \frac{1}{\omega_{cg}^{\mu}}\tan\left[\phi_m + \arctan\omega_{cg}\frac{2\xi_h/\omega_h}{1-\omega^2/\omega_h^2} - \frac{\mu\pi}{2}\right] \\ &\quad \cdot \cos\frac{(1-\mu)\pi}{2} - \frac{1}{\omega_{cg}^{\mu}}\sin\frac{(1-\mu)\pi}{2}. \end{aligned} \quad (15)$$

It can be obtained by the robustness constraint.

$$\begin{aligned} &\left.\frac{d(\arg[L(j\omega)])}{d\omega}\right|_{\omega=\omega_{cg}} \\ &\quad = \frac{K_d\mu\omega^{\mu-1}}{1 + \left[(\sin(1-\mu)\pi + K_d\omega^{\mu})/\cos((1-\mu)\pi/2)\right]^2} \end{aligned}$$

$$+\frac{-2\xi_h}{1+\left[\left(2\xi_h/\omega_h\right)\omega/\left(1-\omega^2/\omega_h^2\right)\right]}\left[\frac{1/\omega^2+1/\omega_h^2}{\left(1/\omega-\omega/\omega_h^2\right)^2}\right] = 0. \quad (16)$$

The K_d function can be obtained using (16).

$$AK_d^2+BK_d+C=0, \quad (17)$$

$$K_d=\frac{-B\pm\sqrt{B^2-4AC}}{2A}, \quad (18)$$

$$\begin{aligned}A &= 2\xi_h\left(\omega_h^2+\omega^2\right)\omega_h^2\omega_{cg}^{2\mu},\\ B &= 4\xi_h\left(\omega_h^2+\omega^2\right)\omega_h^2\sin\frac{(1-\mu)}{2}\omega_{cg}^{\mu} - \mu\omega^{\mu+1}\omega_h^2\cos\frac{(1-\mu)}{2} \quad (19)\\ C &= 2\xi_h\left(\omega_h^2+\omega^2\right)\omega_h^2\cos^2\frac{(1-\mu)}{2} + 2\xi_h\left(\omega_h^2+\omega^2\right)\omega_h^2\sin^2\frac{(1-\mu)}{2}\end{aligned}$$

It can be obtained by using the constraint of the amplitude margin.

$$\begin{aligned}\left|L\left(j\omega_{cg}\right)\right| &= |C(j\omega)||G(j\omega)|\\ &= K_p\sqrt{\left(1+K_d\omega^{\mu}\cos\frac{\mu\lambda}{2}\right)^2+\left(K_d\omega^{\mu}\sin\frac{\mu\lambda}{2}\right)^2} \quad (20)\\ &\cdot\frac{K_q/A}{\omega\sqrt{\left(1-\omega^2/\omega_h^2\right)+\left(\left(2\xi_h/\omega_h\right)\omega\right)}}=1.\end{aligned}$$

Three parameters required by the expression of the PD$^{\mu}$ controller, namely, $K_p = 32, K_d = 0.189, \mu = 0.308$ are obtained with the aid of Matlab-Simulink. The expression of the fractional order PD$^{\mu}$ controller can then be obtained.

$$C(s)=32\left[1+0.189s^{0.308}\right]. \quad (21)$$

4. Input Shaping Technology

Input shaping [28, 29] refers to the convolution of a pulse series with a periodic expected input, and the resulting instruction is used as the actual control instruction of the system to drive the system. Among them, ZD, ZVD, ZVDD, EI, and EI-two hump shaper are widely used in forming [30]. The calculation parameters of each shaper can be calculated by document [31]. The method is applicable to rigid and elastic vibration of the system. The parameters of the input shaper can be suppressed. The input shaper is a pure lag feedforward unit composed of a different gain and the same time interval. Its mathematical expression is

$$I(s)=\sum_{i=1}^{m}A_ie^{-(i-1)sT},\quad (m=2,3\cdots). \quad (22)$$

A_i is the gain, T is the time interval, and m is the number of gains contained in the molding device. The above equation is described as time domain:

$$I(s)=\sum_{i=1}^{m}A_ie^{-(i-1)sT},\quad (m=2,3\cdots). \quad (23)$$

Equation (23) represents the pulse sequence with the amplitude A_i of the first pulse as the time zero and the time interval as T. The input instruction is denoted as $R(t)$, and the molding instruction is denoted as $U(t)$; thus it can be seen that the convolution relation of formula (24) is valid.

$$U(t)=R(t)*I(t). \quad (24)$$

$R(t)$ can be any kind of incentive signal.

In order to realize the precise positioning and trajectory tracking of the manipulator in the underground space, this paper adopts the three-pulse input shaping tool ZVD as the forward feedback controller. The second-order closed-loop transfer function of the manipulator is as follows:

$$\begin{aligned}P(s) &= \frac{C(s)G(s)}{1+C(s)G(s)}\\ &= \frac{\left(\left(k_q/A_p\right)\cdot k_p\left(1+k_ds\right)\right)/s\left(s^2/\omega_h^2+\left(2\xi_h/\omega_h\right)s+1\right)}{1+\left(k_q/A_p\right)k_p\left(1+k_ds\right)/s\left(s^2/\omega_h^2+\left(2\xi_h/\omega_h\right)s+1\right)}\\ &= \frac{\left(k_q/A_p\right)\cdot k_p\left(1+k_ds\right)}{s\left(s^2/\omega_h^2+\left(2\xi_h/\omega_h\right)s+1\right)+\left(k_q/A_p\right)\cdot k_p\left(1+k_ds\right)} \quad (25)\\ &= \frac{1444\times(1+0.189s)}{s\left(s^2/436.81+0.04s+1\right)+1444\times(1+0.189s)}\\ &= \frac{1.038}{\left(s^2/119585+(12.1978/119585)s+1\right)}.\end{aligned}$$

Structure of three-pulse ZVD input shaping is

$$C_2=\sum_{i}^{3}A_ie^{-t_is}=A_1e^{-t_1s}+A_2e^{-t_2s}+A_3e^{-t_3s} \quad (26)$$

where

$$\begin{aligned}A_1 &= \left(1+2K+K^2\right)^{-1},\\ t_1 &= 0;\\ A_2 &= \frac{2K}{\left(1+2K+K^2\right)},\\ t_2 &= \frac{\pi}{\omega_h\sqrt{1-\xi_h^2}};\\ A_3 &= \frac{K^2}{\left(1+2K+K^2\right)}, \quad (27)\\ t_3 &= \frac{2\pi}{\omega_h\sqrt{1-\xi_h^2}};\\ K &= \exp\frac{-\xi_h\pi}{\sqrt{1-\xi_h^2}}\end{aligned}$$

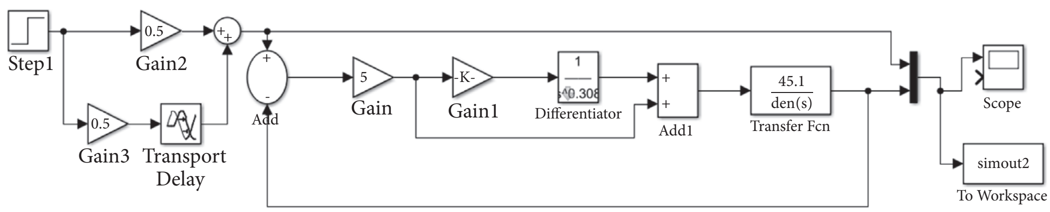

Figure 5: Manipulator of mine-used bolter "input shaping + fractional order PD^{μ} controller" system model.

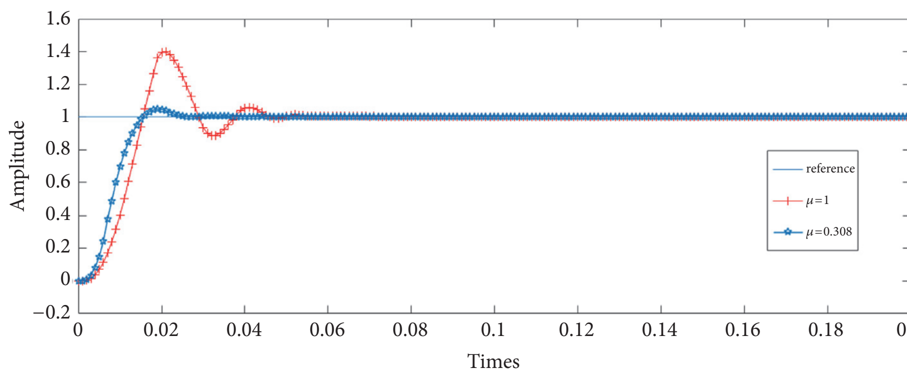

Figure 6: Comparison of unit step response between fractional order PD^{μ} controller and integer order PD controller.

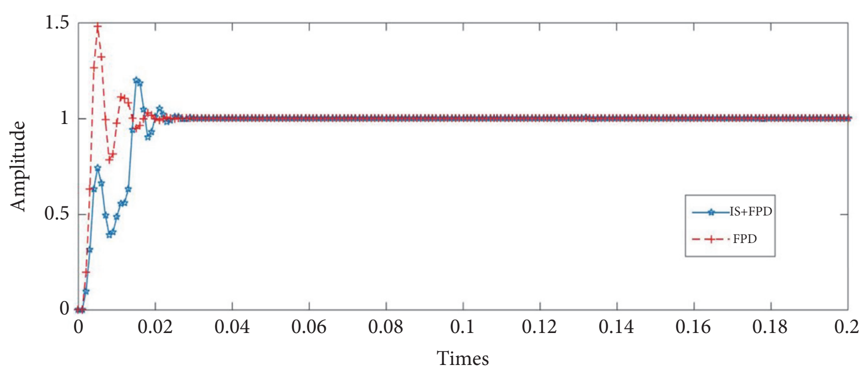

Figure 7: Comparison of unit step response between fractional order PD^{μ} controller and "input shaping + fractional order PD^{μ}".

Time delay is

$$T = \frac{2\pi}{\omega_h \sqrt{1-\xi_h^2}} = 0.0182, \tag{28}$$

where $\omega_h = 345.8105$; $\xi_h = 0.0176$,

5. Modeling and Simulation of the Control System

5.1. Modeling of the PD^{μ} Control System. Under the environment of Matlab-Simulink, the fractional order PD^{μ} controller is used to control the valve-controlled cylinder of the space position and attitude actuator of the manipulator of the mine-used bolter. The unit step signal is used as input signal, and the valve-controlled cylinder at each joint position of the manipulator of the mine-used bolter is used as a control object. The control model is set up as shown in Figure 5.

5.2. Simulation of the Control System. The control effects of fractional order PD^{μ} controller and integer order PD controller on system stability are compared, as shown in Figure 6. Finally, a compound control method, i.e., input shaper + fractional order PD^{μ} control, is adopted to apply on the control system. The stability of the system is numerically analyzed and compared with that of a single fractional order PD^{μ} controller, as shown in Figure 7.

Figure 6 compares the unit step response of a fractional PD^{μ} controller and that of an integer order PD controller. Figure 6 shows that a fractional order controller PD^{μ} has a better control effect than an integer order PD controller in response speed, adjustment time, and steady-state accuracy. The simulation results show that, under the influence of a fractional order PD^{μ} controller, the maximum amplitude of the control system is 1.4, and the stability time is 0.055s; under the influence of an integer order PD controller, the maximum amplitude is 1.1, and the stability time is 0.022s. Through numerical simulation comparison, it can be seen that the maximum amplitude of the control system is reduced by 75% compared with the stability value 1 of the system, and the stability time is reduced by 60%, which fully reflects the superiority of the fractional order PD^{μ} controller.

The step response of fractional order PD^{μ} controller is compared with that of "input shaping + fractional order PD^{μ} control", as shown in Figure 7. It can be seen that the control system quickly tends to be stable when the compound control "input shaping device + fractional order PD^{μ} controller" is adopted. In particular, the maximum amplitude decreases significantly from 1.5 to 1.25. Compared with the stability value 1, the maximum amplitude decreases by 50%, and the control system quickly tends to the stable stage. Underground, the reduction of maximum amplitude is of great significance to the work of the manipulator of a mine-used bolter and provides guaranteed accuracy and safety of roof or side support. The high precision positioning of the manipulator could avoid the interference between the equipment and the coal wall and improves the safety of underground workers and equipment.

In the environment of Matlab-Simulink, the simulation model of the mathematical models of controlled objects and the composite controllers are built in this section, which proves the effectiveness and superiority of the method.

6. Conclusions

Taking the manipulator of mine-used bolter as the research object, in order to realize the space trajectory tracking and accurate positioning of the manipulator, the following work has been done.

(1) The mathematical model of the electrohydraulic proportional control system of the manipulator was solved, and the PD^{μ} controller was formulated based on a fractional order algorithm. Based on the definition and classification of input shaping technology, a ZVD feedforward controller was designed.

(2) Under the Matlab-Simulink environment, the control system model was built and numerical simulation was carried out. The fractional order PD^{μ} controller and the integer order PD controller were compared with the control effect of the system. Under the influence of a fractional order PD^{μ} controller, the maximum amplitude of the control system was reduced by 75%, and the stabilization time was reduced by 60%. It is verified that a fractional order PD^{μ} controller has superiority over an integer order PD controller in response speed, adjusting time and steady-state accuracy.

(3) Finally, the control effects of "input shaping + fractional order PD^{μ} controller" and "input shaping + fractional order PD^{μ} controller" on system stability were compared. With the "input shaping + fractional order PD^{μ} control", the maximum amplitude of the system was significantly reduced by 50%. In underground operation, the reduction of the maximum amplitude can effectively improve the positioning accuracy of the end of the manipulator, ensure the supporting effect of the roadway, and further improve the safety of equipment and personnel. The method of "input shaping + fractional order PD^{μ} control" developed in this paper can restrain the oscillation of the manipulator of the mine-used bolter in the process of trajectory tracking and precise positioning, so that the control system has strong anti-interference ability and good robustness. The composite control method provides a theoretical support for the precise positioning of the manipulator. At the same time, the high stability and high safety of the manipulator of the mine-used bolter also expand the scope and depth of the application of the composite control method.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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