Design of Mechanical Transmission Control System for Medium and Small Logistics

Dalong Liu, Yanfang Pan, Liwe Li
NanNing University, NanNing, 530200, China

Abstract: The transmission characteristics of medium and small logistics machinery in the working process can effectively feedback the working conditions of the machinery, the optimization design of transmission control can improve the overall stability of medium and small logistics machinery. A new control method of medium and small logistics machinery based on variable structure fuzzy PID and steady state regulation is proposed. The controlled object model and control constraint parameter model of medium and small logistics machinery control are constructed. The fuzzy PID variable structure control method is used to optimize the control algorithm of mechanical transmission. Combined with steady error tracking and inertial fusion of transmission system, Kalman filtering is carried out to reduce the output steady state error of logistics machinery and realize the optimal design of control rules. The hardware of the control system is designed under the embedded ARM environment. The main control circuit module, the embedded control module and the integrated information processing module are designed optimally. The test results show that the control system can effectively realize the control of medium and small logistics machinery, and the quality of the control is good.

Keywords: small and medium-sized logistics machinery; transmission control; fuzzy PID; embedded ARM

1. Introduction

With the development of intelligent machining technology, the precision and intelligence of mechanical control are required higher. The optimization control of medium and small logistics mechanical transmission system can effectively improve the logistics efficiency. The middle and small logistics mechanical transmission system is the core part of the whole mechanical intelligent system[1]. The mechanical transmission system realizes the power output by torsion moment, and controls the mechanical parts and the mechanical transmission actuator to carry on the corresponding machining work. In the working process of mechanical transmission system, it is easy to be affected by external factors such as buffeting and flutter, which leads to poor output stability of torsional torque. It has great significance to study the optimal control method of medium and small logistics machinery transmission to improve the intelligence of logistics machinery[2].

In the optimization design of medium and small logistics mechanical transmission control, the key technology is how to construct the mathematical control model of mechanical balance of medium and small logistics mechanical transmission, and combine the theory of torsional moment balance to carry out vibration suppression and disturbance tracking[3]. To improve the accuracy of transmission output, the torsional vibration control of medium and small logistics mechanical transmission system is an unsteady nonlinear control process. Traditionally, fuzzy control theory is mainly used for the small and medium-sized logistics mechanical transmission control. Neural network control model and inverse integral control method are used to design the control law according to the constraint parameter model of transmission control to improve the accuracy and stability of the transmission control of medium and small logistics mechanical transmission, and some research results have been obtained. In reference [4], a torsional balance control strategy based on Lyapunov stability compensation is proposed for medium and small logistics mechanical transmission system, and the inertial navigation control model of medium and small logistics mechanical transmission system under torsional moment flutter condition is constructed. The control constraint parameter is analyzed and the control optimization of medium and small logistics mechanical transmission system is carried out by using Lyapunov stability principle to improve the balance of transmission power output. However, this method has the advantages of high complexity, poor performance reliability and poor real-time performance in the process of medium and small logistics mechanical transmission control. In reference [5], a dynamic control model based on adaptive linear equalization control for small and medium-sized logistics mechanical transmission is proposed. The vibration suppression and small disturbance control are carried out by taking the moment of rotation and the moment of torsion as constraint parameters, and the stability of the system is improved. However, this control method cannot effectively eliminate the steady-state error in the mechanical transmission control of medium and small logistics, and the convergence of the system is not good.

In order to solve the above problems, this paper presents a control method of medium and small logistics machinery based on variable structure fuzzy PID and steady state regulation. The controlled object model and control constraint parameter model of small and medium-sized logistics machinery control are constructed, the control algorithm optimization design and the control system hardware design are carried out. Finally, the simulation test of the control system is carried out. The superior performance of this method in improving the control stability of medium and small logistics mechanical transmission is demonstrated.

2. Control Constraint Parameters and Description of Controlled Object

Stability control of the transmission of the medium and small logistics machinery is constructed based on the measurement of the parameter information of the medium and small logistics machinery in working state. The transmission characteristics of small and medium-sized logistics machinery are carried out by sensor equipment and sensitive elements. The fuzzy control object model of transmission is established by using the Smith model shown in figure 1[6].

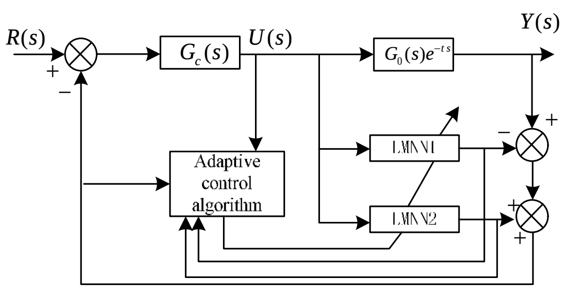


Figure 1. Control structure model of medium and small scale logistics machinery

In the limited initial state, the three-channel output model of the transmission control parameters of medium and small logistics machinery can be expressed as follows:

$$\begin{cases} \ddot{j}_a = -(b_1+\Delta b_1)\dot{j}_a - (b_2+\Delta b_2)j_a - (b_3+\Delta b_3)d_j + fd_1 \\ \ddot{y}_a = -(b_1+\Delta b_1)\dot{y}_a - (b_2+\Delta b_2)y_a - (b_3+\Delta b_3)d_y + fd_2 \\ \ddot{g} = -(d_3+\Delta d_3)d_g + fd_3 \end{cases} \quad (1)$$

Where, j_a, y_a, g are the vibration amplitudes of medium and small-sized logistics machinery, $\dot{j}_a$, $\dot{y}_a$, $\dot{g}$ are the swing rod rotation angular velocity values, b_1, b_2, b_3, d_3 are the steady-state regulation coefficients of the logistics mechanical drive control, Δb_1, Δb_2, Δb_3, Δd_3 are the output gains of the logistics mechanical drive control, and fd_1, fd_2, fd_3 are the interference terms, d_j, d_y, d_g are the torque parameters of the mechanical transmission.

3. Optimal Design of Control Algorithm

3.1. Fuzzy variable structure PID control

On the basis of constructing the constraint parameter model of medium and small logistics mechanical transmission control, the control algorithm optimization design is carried out. In this paper, a variable structure PID fuzzy control method for middle and small logistics mechanical transmission optimization control is proposed[7]. The fuzzy PID variable structure control method is used to optimize the control algorithm of mechanical transmission. Combined with steady error tracking and inertial fusion of transmission system, Kalman filtering is carried out, and the fuzzy PID structure is obtained as shown in figure 2.

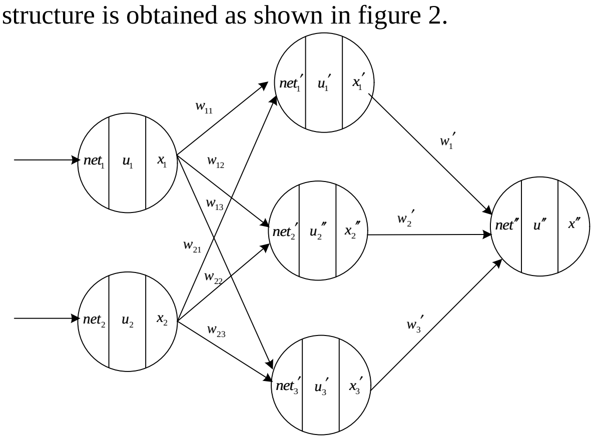


Figure 2. Variable structure PID neural network model

The principle of small disturbance suppression is used to deal with vibration defibrillation of medium and small logistics mechanical transmission system. The linear disturbance control parameter and the constraint variable of torsional drive control of medium and small logistics mechanical transmission system are composed of determined and uncertain parts, as:

$$M = M_n + \Delta M \quad (2)$$

$$h(j_a, \dot{j}_a) = h_n(j_a, \dot{j}_a) + \Delta h(j_a, \dot{j}_a) \quad (3)$$

The steady state error compensation for vibration of medium and small logistics mechanical transmission system can be further obtained:

$$M_n\ddot{j}_a + h_n(j_a,\dot{j}_a) = u(t) + r(t) \tag{4}$$

When the upper bound is known, the fuzzy variable structure PID method is used to realize the optimal design of the control algorithm.

3.2. Kalman filtering and steady-state regulation of control parameters

Combined with steady-state error tracking and inertial fusion of transmission system, Kalman filtering is carried out to reduce the output steady-state error of logistics machinery, and a self-regression model for determining parameters of transmission control of small and medium-sized logistics machinery is obtained:

$$\begin{cases} e_1 = j_a - j_{ad} \\ e_2 = \dot{j}_a - \dot{j}_{ad} \end{cases} \tag{5}$$

The tracking error integral item is added to the determination parameter model, and the error vector form of medium and small logistics mechanical transmission control is obtained by using Kalman filtering method.:

$$\begin{cases} \dot{e}_1 = e_2 \\ \dot{e}_2 = M_n^{-1}u - M_n^{-1}h_n(j_a,\dot{j}_a) - \ddot{j}_{ad} \end{cases} \tag{6}$$

According to the principle of Lyapunov stability, set:

$$\dot{s} = 0 \tag{7}$$

Combined with the parameter identification model of medium and small size logistics mechanical transmission control, the error compensation of medium and small size logistics mechanical transmission control is realized under the condition of small disturbance[8]. The output steady state error is obtained as follows:

$$\begin{aligned} & ce_2 + \dot{e}_2 \\ & = ce_2 + \ddot{j}_a - \ddot{j}_{ad} \\ & = ce_2 + M_n^{-1}u - M_n^{-1}h_n(j_a,\dot{j}_a) - \ddot{j}_{ad} \\ & = 0 \end{aligned} \tag{8}$$

By using the steady-state regulation method, the control rules of medium and small logistics mechanical transmission control are obtained as follows:

$$\begin{aligned} \hat{r}(x,w) = & w_1's_1(j_a,\dot{j}_a) + w_2's_2(j_a,\dot{j}_a) \\ & + w_3's_3(j_a,\dot{j}_a) \end{aligned} \tag{9}$$

In summary, Kalman filtering is carried out by combining steady-state error tracking and inertial fusion of transmission system to reduce the output steady-state error of logistics machinery and realize the optimal design of control rules.

4. Hardware Design and Realization of the Control System

The hardware design of the middle and small logistics mechanical drive control system is based on embedded ARM. The hardware structure of the system includes the main control circuit module, the embedded control module and the integrated information processing module, among which the control actuator uses Mux101 multiplex switch to control the terminal position and posture of the small and medium-sized logistics mechanical drive control system.

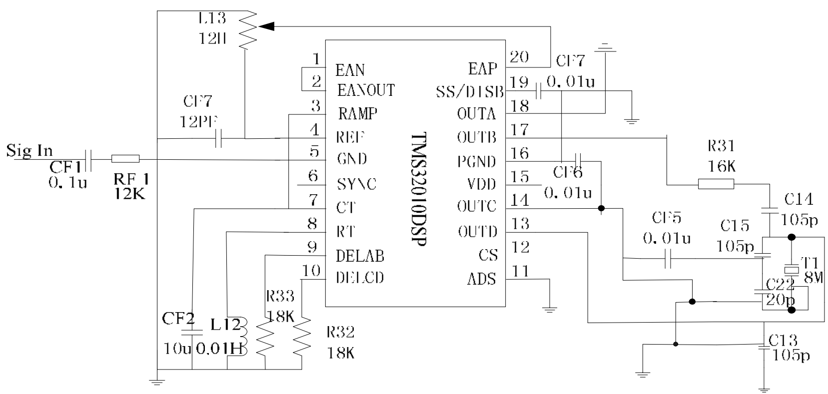
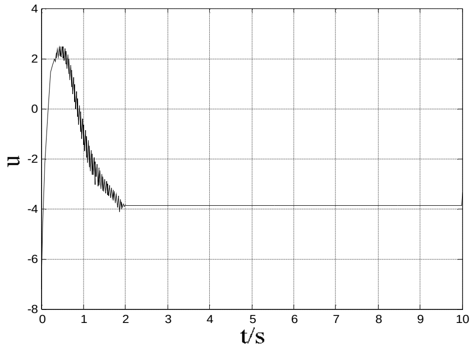


Figure 3. Hardware design of control system

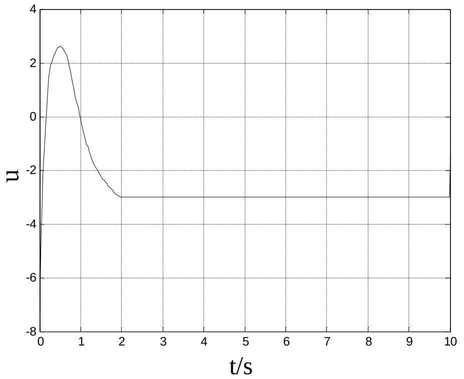
The central control module is introduced into the DAQ-STC to modify the mechanical parameters of the transmission system of the logistics machinery. The embedded ARM is used to drive the control system and load the control instructions. The control circuit takes the S3C2440A ARM9 processor as the control core board. Combined with the interface circuit and the central integrated processor, the optimal design of the small and medium-sized logistics mechanical transmission control system is realized, and the hardware circuit is obtained as shown in Figure 3.

5. System Simulation Test

In order to test the application performance of the small and medium-sized logistics mechanical transmission control system designed in this paper, the simulation experiment is carried out. The experiment is designed with Matlab R2010b software. The medium and small logistics mechanical transmission system adopts Machine2015 as the research object. The maximum number of iterations is set to MaxCycles100, the moment of inertia is 28.98 N.s, the torsion deviation is 0.3radunder the control of the transmission error of the logistics machinery, the initial moments of the logistics machinery are $a_x = 0.1859, b_q = 3.9508$, and the interference coefficients of the steady-state error are $l_x = 0.8623, l_q = 3.9753$, according to the simulation environment and the parameters mentioned above. The control curves before and after the intervention of the control law are compared as shown in Figure 4.



(a) Before control law intervention



(b) After control law intervention

Figure 4. Comparison of control performance curves

Figure 4 shows that the control system designed in this paper can effectively realize the control of medium and small logistics machinery, and the error of the control system is smaller, the control quality is improved.

6. Conclusions

In the paper, a new control method of medium and small logistics machinery based on variable structure fuzzy PID and steady state regulation is proposed. The controlled object model and control constraint parameter model of medium and small logistics machinery control are constructed. The fuzzy PID variable structure control method is used to optimize the control algorithm of mechanical transmission. Kalman filtering is carried out to reduce the output steady state error of logistics machinery and realize the optimal design of control rules. The hardware of the control system is designed under the embedded ARM environment. The test results show that the control system can effectively realize the control of medium and small logistics machinery, and the quality of the control is good, it has good application value in machine control.

Acknowledgement

Scientific research of Nanning College (No. 2017XJ17).

References

[1] WANG Jungang, TANG Lei, GU Guoying, ZHU Xiangyang. Tip-following Path Planning and Its Performance Analysis for Hyper-redundant Manipulators[J]. Journal of Mechanical Engineering, 2018, 54(3): 18-25.

[2] Tang L,Wang J,Zheng Y,et al. Design of a cable-driven hyper-redundant robot with experimental validation[J]. The International Journal of Advanced Robotic Systems,2017,14(5):1-12.

[3] Si Y Y, He B. Walking control of biped robot based on CPG and CA-CMAC[J]. System Simulation Technology, 2017, 13(1): 6-10.

[4] Gao Q, Wang Z L, Hu W J, et al. Gait simulation of snake robot based on CPG method[J]. Journal of System Simulation, 2015, 27(6): 1374-1380.

[5] Zhang X L, Gong J Q, Yao Y A. Effects of head and tail as swinging appendages on the dynamic walking performance of a quadruped robot[J]. Robotica, 2016, 34(12): 2878-2891.

[6] Shi R D, Zhang X L, Tian Y B, et al. A CPG-based control method for the rolling locomotion of a desert spider[C]//IEEE Workshop on Advanced Robotics and Its Social Impacts. Piscataway, USA: IEEE, 2016: 243-248.

[7] Tunc L T, Shaw J. Experimental study on investigation of dynamics of hexapod robot for mobile machining[J]. International Journal of Advanced Manufacturing Technology, 2016, 84(5-8): 817-830.

[8] Wang Z L, Gao Q, Zhao H Y. CPG-inspired locomotion control for a snake robot basing on nonlinear oscillators[J]. Journal of Intelligent and Robotic Systems, 2017, 85(2): 209-227.