CHEMICAL ENGINEERING TRANSACTIONS
VOL. 71, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Xiantang Zhang, Songrong Qian, Jianmin Xu

ISBN 978-88-95608-68-6; **ISSN** 2283-9216
DOI: 10.3303/CET1871174

Electromechanical Feed Control System in Chemical Dangerous Goods Production

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Hazardous chemicals have the character of inflammability, explosion, toxicity and corrosion. Therefore, to design an efficient electromechanical feed control system instead of manual operation in the production and packaging process can reduce the risk greatly. In this paper, MATLAB software is used to establish a simulation model of an electromechanical feeding control system. Through simulation, the static and dynamic characteristics of the feeding system are tested, and a suitable correction device is selected to improve the performance of the system so as to obtain a satisfactory control scheme. The simulation model of a servo control system is established by an example, and the performance of the control system is analysed. The performance of the system is improved by PID correction, and the control system which meets the requirements of the design is obtained.

1. Introduction

With the rapid development of the control theory, the control effect is more and more demanding, the control algorithm is more and more complex, and the design of the controller is becoming more and more difficult. The computer aided design of the control system has been paid much attention by the control circle (Qiu et al., 2013; Xiong et al., 2012). However, using a general computer programming language, it takes a lot of time and is difficult to achieve satisfactory results in the compilation and debugging of programs, especially for beginners and general engineering technicians. In many cases, it is difficult to determine the correctness of the program and the accuracy of the system response (Yang et al., 2013). The birth of MATLAB software makes the analysis and design of control system simpler. Because the software has the characteristics of easy to use, strong matrix operation and rich control theory and CAD application toolbox, it has become the most popular auxiliary simulation software of the electromechanical control system in the field of international control (Qian et al., 2012; Wang et al., 2012). MATLAB software provides powerful matrix processing and drawing functions. It has high credibility and is very suitable for computer-aided design of control systems. In particular, the dynamic system modeling and simulation tool SIMULINK integrated in it makes the analysis, synthesis and design of the control system free from complex differential equation solving, association matrix input and retrieval, so that more energy is put on the performance analysis, design and correction of the system.
The electrical control system refers to a combination of several electrical components used to realize the control of a certain object or objects, so as to ensure the safe and reliable operation of the controlled equipment (Sudharsan and Karunamoorthy, 2015). The main functions of electrical control system are automatic control, protection, monitoring and measurement. It mainly consists of three parts: input (such as sensor, switch, button, etc.), logic (such as relay, electric shock, etc.) and execution (such as electromagnetic coil, indicator light, etc.) The technological design of electrical control system is to meet the requirements of manufacturing and using electrical control equipment (Khlifi, 2016). After completing electrical schematic design and selection of electrical components, the overall configuration of electrical control equipment can be carried out. In order to ensure the reliability and safety of primary equipment operation, many auxiliary electrical equipment are required to serve it (Oshaba et al., 2015). The combination of several electrical components which can realize a certain control function is called the control loop or the secondary loop. Electrical control system diagram is the theoretical basis of electrical circuit installation, debugging, use and

Please cite this article as: Guo G., 2018, Electromechanical feed control system in chemical dangerous goods production, Chemical Engineering Transactions, 71, 1039-1044 DOI:10.3303/CET1871174

maintenance, which mainly includes electrical schematic diagram, electrical installation wiring diagram and electrical component layout diagram (Khalifa et al., 2015). The electrical control principle of the electrical equipment used in the system is used to guide the installation of electrical equipment and the debugging operation of the control system. Electrical control system diagram as shown in Fig.1.

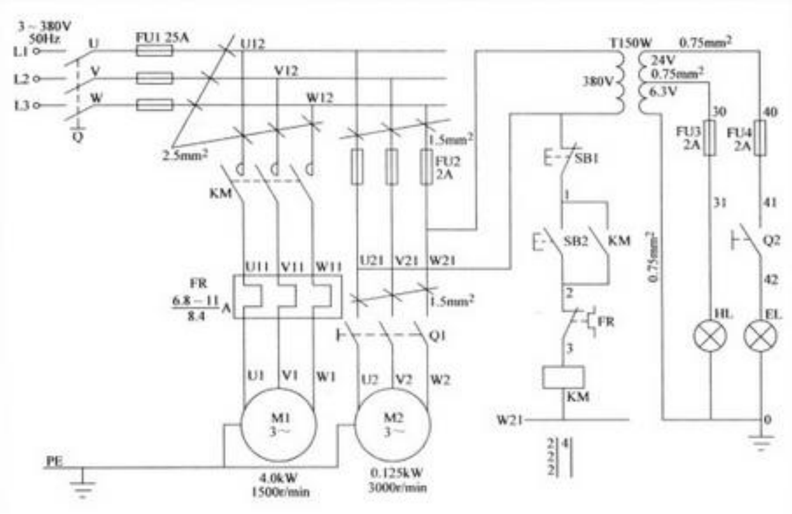

Figure 1: Electrical control system diagram

2. MATLAB Basic Knowledge

MATLAB is a kind of commercial mathematical software produced by the MathWorks company in the United States. It is used for advanced technical computing language and interactive environment for algorithm development, data visualization, data analysis and numerical calculation, mainly including two parts of MATLAB and Simulink. It is a high-tech computing environment mainly released by MathWorks company, which is mainly faced with scientific computing, visualization and interactive programming [6, 7]. It integrates many powerful functions, such as numerical analysis, matrix calculation, scientific data visualization, modeling and Simulation of nonlinear dynamic systems, in an easy to use window environment. It provides a comprehensive solution for scientific research, engineering design, and many scientific domains that must be effective numerical calculation. It represents the advanced water of the international scientific computing software.

MATLAB can be applied to engineering computing, control design, signal processing and communication, image processing, signal detection, financial modeling design and analysis. The basic data unit of MATLAB is a matrix, and its instruction expression is very similar to the common form of mathematics and engineering [8]. So it is much simpler to use MATLAB to solve the problem than to use C, FORTRAN and other languages and MATLAB also absorbs the advantages of software such as Maple, making MATLAB a powerful mathematical software. The default operating interface of MATLAB is shown in Figure 2.

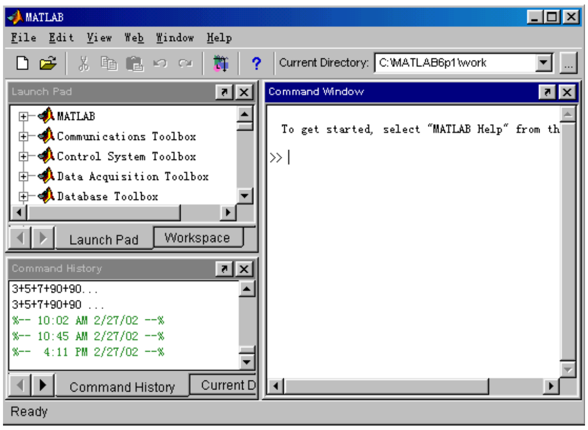

Figure 2: The default operating interface of MATLAB.

3. Simulation Analysis of System

3.1 Mathematical model and performance index

Armature circuit voltage balance equation:

$$u_a(t) = L_a \frac{di_a(t)}{dt} + R_a i_a(t) + E_a \tag{1}$$

In the equation (1), E is the counter electromotive force of the armature. It is produced when rotating the electric digital. The size is proportional to the excitation flux and revolving speed, and the direction is opposite to the armature voltage $U_a(t)$.
Electromagnetic torque equation:

$$M_m(t) = C_m i_a(t) \tag{2}$$

In the equation (2), C_m(N.m/A) is the moment coefficient of the motor, $M_m(t)$(N.M) is the electromagnetic torque produced by the armature current.
Torque balance equation of motor shaft:

$$J_m \frac{d\omega_m(t)}{dt} + f_m \omega_m(t) = M_m(t) - M_c(t) \tag{3}$$

In the equation (3), f_m(N.m/rad/s) is the viscous friction coefficient converted by the electromotor and load in the motor shaft; J_m(kg.m.s2) is the rotational inertia converted by the electromotor and load in the motor shaft.
Erasing the intermediate variables $i_a(t)$, E_a and $M_m(t)$ in (1) to (3), wm(t) can be obtained as the output quantity, and the DC motor differential equation with the input quantity of $u_a(t)$ is:

$$\begin{aligned} L_a J_m \frac{d^2\omega_m(t)}{dt^2} + (L_a f_m + R_a J_m)\frac{d\omega_m(t)}{dt} + (R_a f_m + C_m C_e)\omega_m(t) \\ = C_m u_a(t) - L_a \frac{dM_c(t)}{dt} - R_a M_c(t) \end{aligned} \tag{4}$$

For the armature circuit inductance La is smaller in the engineer, it can be neglected, therefore, the above formula can be simplified as:

$$T_m \frac{d\omega_m(t)}{dt} + \omega_m(t) = K_1 U_a(t) - K_2 M_c(t) \tag{5}$$

In the equation (5),

$$T_m = \frac{R_a J_m}{R_a f_m + C_m C_e} \tag{6}$$

$$K_1 = \frac{C_m}{R_a f_m + C_m C_e} \tag{7}$$

$$K_2 = \frac{R_a}{R_a f_m + C_m C_e} \tag{8}$$

The motor's transfer function from the control voltage to the angular displacement can be obtained after the LAPLACE conversion:

$$G(s) = \frac{\theta(s)}{U(s)} = \frac{1/C_e}{s(T_m s + 1)} \tag{9}$$

In the formula, 1/Ce is the velocity constant, and Tm is the mechanical time constant.
Computer simulation uses mathematical models to obtain some important characteristic parameters of the system. These mathematical models are usually described by ordinary differential equations with time as variables, and are solved by computer simulation by numerical calculation [9]. Besides differential equations,

control systems are usually described by transfer functions and state equations. The open loop transfer function of the system is as follows:

$$G_0 = \frac{200}{s(0.05s+1)(0.01s+1)} \tag{10}$$

The performance index required by this servo system is:
System bandwidth:

$$W_B \geq 200rad/s, that is, f_B \geq 3Hz \tag{11}$$

Response time:

$$t_s \leq 0.4s \tag{12}$$

Static position error:

$$e_p = 0 \tag{13}$$

Phase margin:

$$r \geq 45^{o} \tag{14}$$

The overshoot is no more than 20%. Analyse whether the static and dynamic characteristics of the system meet the control requirements.

3.2 Build a simulation model

It is very convenient to establish the simulation model of control system in MATLAB environment. Its integrated SIMULINK is a visual dynamic system simulation environment. It provides the component library of signal source, output pool, continuous, discrete, mathematical operation, nonlinear, function and table [10]. The establishment of simulation model is the process of selecting components from the component library and setting up initial parameters and connecting them. The simulation model of servo system created by SIMULINK is shown in Figure 3.

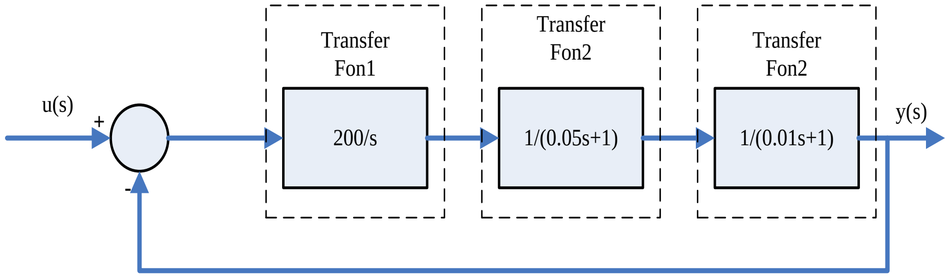

Figure 3: SIMULINK simulation model of servo system.

3.3 Simulation analysis

SIMULINK provides a visual simulation environment for linear constant system-LTI Viewer. In this environment, the model of the system can be input from MATLAB workspace or SIMULINK, and the corresponding curves are drawn according to the different requirements, such as the order response curve, the impulse response curve, the Bode diagram and the Nyquist diagram and the Nichols diagram and so on [11]. From different curves, various parameters can be obtained, such as transition process time, peak point, gain margin, phase angle margin, resonance peak and so on, which can be used to analyse the performance of the system. As shown in Figure 4, the closed loop step response curve of servo system shows that the response curve is increasing and oscillating, and the system is unstable, so it must be corrected.

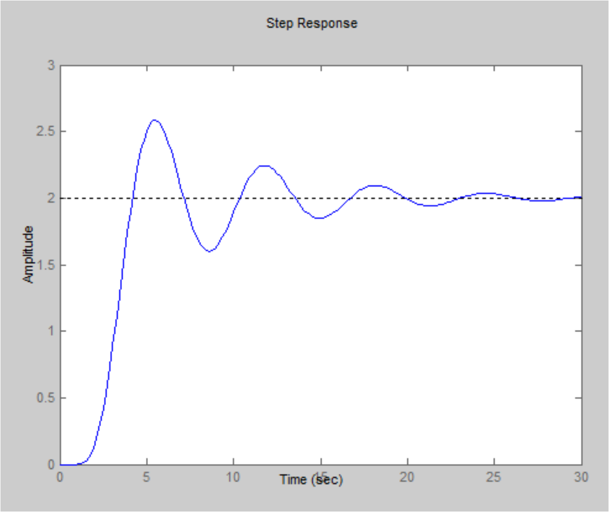

Figure 4: Closed-loop step response curve of the service system.

4. Control System Correction

4.1 PID correction

When the system is not satisfied with the requirements of the specified performance index, the compensation device must be introduced in the system, that is, the correction device, the correction of the system, or the redesign of the system. Series correction and feedback correction are the most commonly used correction methods in electromechanical control systems [12]. PID correction is used here. PID correction, the proportional integral differential correction, changes the performance index of the system by adjusting the parameters of the PID regulator. It has the advantages of simple principle, strong adaptability and strong robustness, so it is widely used in the field of industrial control. In SIMULINK, adding correction device is quite convenient [13]. As shown in Figure 5, PID adjuster is added on the basis of the original simulation model.

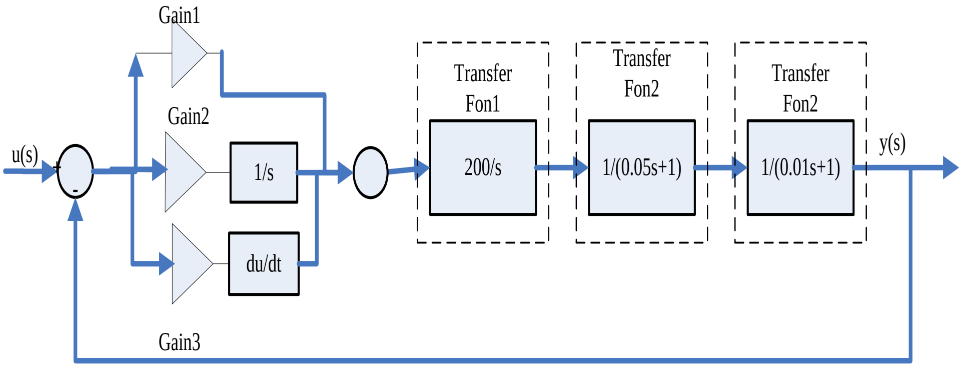

Figure 5: Simulation model with PID correction device.

4.2 Selection of PID parameters

In the MATLAB environment, PID parameters can be directly selected according to the simulation curve. According to the system performance indicators and some basic experience of selecting parameters, different PID parameters are selected for simulation, and finally the satisfactory parameters are determined [14, 15]. On the one hand, it is more intuitive, and on the other hand, the amount of computation is relatively small, and it is easy to adjust. Adjust the different parameters of PID to get the different selectable response curves shown in Figure 6.

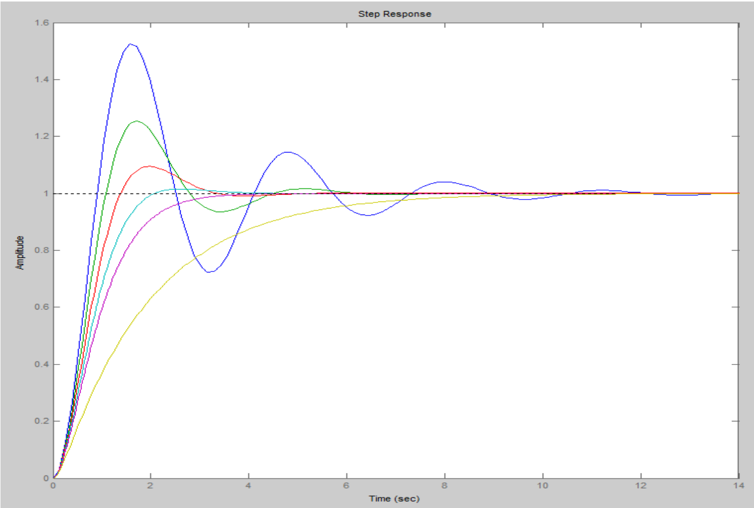

Figure 6: Simulation model with PID correction device

5. Conclusions and Future Work

The analysis of control system is to calculate and estimate their performance under the condition that the system structure and parameters have been determined. On the other hand, the controlled object is known and the performance index is given in advance. It requires the designer to choose the appropriate structure and parameters to make the controller and the controlled object a system that satisfies the performance requirements. This is the synthesis and design of the system, which is also the requirement of the engineering practice. Using MATLAB / SIMULINK, it is easy to establish the simulation model of the control system, simulate the system, quickly generate the curves and charts of various time domain response and frequency response, and obtain the time domain and frequency domain indexes of the system, and provide the basis for judging the stability, rapidity and accuracy of the system. At the same time, it is very convenient for correcting the design of control system to achieve the best design requirements.

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