Research of PID Control Simulation of Magnetic Bearing System Based on Labview

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Abstract: Active magnetic bearing system is a run-time control system,using NI LabVIEW which is a software platform with the features of modifing the parameters easily and applicating the codes conveniently to simulate the PID control algorithm of active magnetic bearing system. In this paper, we designed PID control algorithm and did simulation for active magnetic bearing system.This paper presents the mixed program between LabView and MatLab based on MatLab Script by the interface of LabView for Active magnetic bearing system simulation. The results of simulation show that the PID control algorithms has good dynamic and stability for active magnetic bearing system;With the Com technology, the LabView program can get more powerful algorithm supports from MatLab. The mixed programming of MatLab and LabView combines the advantages of both and makes it very promising in the engineering system.

• PAPER GUIDELINES

A. *Introduction*

Magnetic bearing is a typical mechanical electronic product. Its research involves many learning knowledge, such as mechanics, rotor dynamics, electromagnetism, electronics, control theory and computer science. It has a series of excellent qualities, such as contact free, frictionless, no wear, no lubrication and sealing. With electronics and computers The development of the magnetic bearing technology is more and more widely used in various industrial fields, which fundamentally changed the traditional form of support. Therefore, this technology has been paid more and more attention and attention by more and more experts and scholars at home and abroad and paid attention to [1].

The maglev system is a unstable two order system. We must add controller and close loop control to stabilize it. Aiming at the characteristic of magnetic bearing, this paper chooses the method based on PID control, and its principle is simple, application is convenient, and it has strong robustness. The software system [2] based on LabVIEW development platform has the characteristics of strong interface development ability, but it lacks the powerful computing power of Matlab. In order to improve the development efficiency of the application, the Matlab Script node is used to realize the hybrid programming in LabVIEW, and the advantages of the two are combined to make it more efficient.

B. *Mathematical model of magnetic suspension bearing*

The rotor of the magnetic bearing system has 5 degrees of freedom, 5 degrees of freedom along the translation and rotation along the X and Y axis and the translation along the Z axis. After decoupling [3-4] from 5 degrees of freedom, the 5 degrees of freedom are separated and studied. In terms of control, the structure of 5 degrees of freedom is basically the same. Therefore, a single degree of freedom magnetic bearing system is simulated and analyzed in this paper.

The magnetic bearing system mainly consists of electromagnet, rotor, displacement sensor, controller and power amplifier.

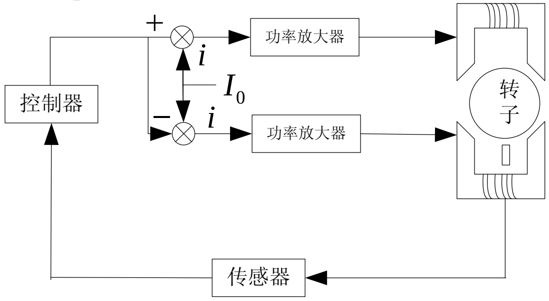


Figure 1 magnetic bearing system diagram

In general, each degree of freedom works with a pair of electromagnets, using a differential mode of work, a sum of a bias current and a control current, and the other using the difference between the two. Changing the control current can make the electromagnet generate different suction sizes to control the rotor's stability in the specified position.

The mechanical mathematical model of magnetic bearing is as follows:

$$F = F_1 - F_2 = \frac{\mu_0 sN^2 (I_0 + i)^2}{4(x_0 - x)^2} - \frac{\mu_0 sN^2 (I_0 - i)^2}{4(x_0 + x)^2}$$

(1)

Based on the linearization theory, the Taylor expansion of the formula (2) is carried out at the equilibrium point, ignoring the higher order infinitesimal.

$$F = k_x x + k_i i_c \tag{2}$$

$$k_x = \frac{\mu_0 s N^2 I_0^{\,2}}{x_0^{\,3}}, \quad k_i = \frac{\mu_0 s N^2 I_0}{x_0^{\,2}} \qquad (3)$$

According to Newton's second law, without considering other forces acting on an object, the mechanical equations in the X direction are:

$$m\ddot{x} = k_x x + k_i i_c \qquad （4）$$

Medium: k_x It is called the force displacement coefficient, which reflects the stiffness of the electromagnet.

k_i : It is called a force current coefficient, which reflects the control ability of the control system.

The transfer function of magnetic bearing can be expressed as:

$$G(s) = \frac{X(s)}{I(s)} = \frac{k_i}{ms^2 - k_x} \qquad (5)$$

Simulation parameters:

Quality m=25kg; $k_x = 450000N/m$; $k_i = 56.2N/A$

C. Incomplete differential PID control strategy

In PID control, the introduction of differential signals can improve the dynamic characteristics of the system, but it is easy to introduce high frequency interference. The deficiency of the differential term will be particularly prominent when the error disturbance is abrupt. Therefore, adding low-pass filter to control algorithm can improve the performance of [5] very well.

One way to overcome these shortcomings is to add a first order inertial link (lowpass filter) in the PID algorithm $G_f(s) = \frac{1}{1+T_f s}$, which can improve the system performance.

The incomplete differential PID structure, as shown in the graph, is directly loading the differential link on the lowpass filter.

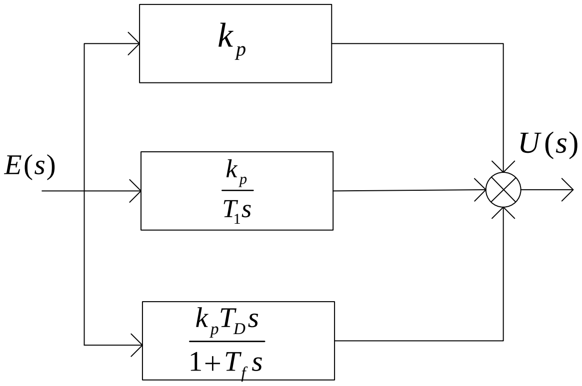


Figure 2 incomplete differential PID structure diagram

The incomplete differential structure shown in the graph is the transfer function:

$$U(s) = (k_p + \frac{k_p}{T_I s} + \frac{k_p T_D s}{T_f s + 1})E(s) = U_P(s) + U_I(s) + U_D(s)$$

(6)

The formula is discretized as follows:

$$u(k) = u_p(k) + u_I(k) + u_D(k) \qquad (7)$$

Now $u_D(k)$ deduce

$$u_D(k) = \frac{k_p T_D s}{T_f s + 1} E(s) \qquad (8)$$

Write out differential equation

$$u_D(k) + T_f \frac{du_D(t)}{dt} = k_p T_D \frac{derror(t)}{dt} \qquad (9)$$

The sampling time is T_s , and the upper form is discretized

$$u_D(k) + T_f \frac{u_D(k) - u_D(k-1)}{T_s} = k_p T_D \frac{error(k) - error(k-1)}{T_s}$$

(10)

Collate as follows:

$$u_D(k) = \frac{T_f}{T_f + T_s} u_D(k-1) + k_p \frac{T_D}{T_f + T_s}(error(k) - error(k-1))$$

(11)

So $\alpha = \frac{T_f}{T_f + T_s}$, then $\frac{T_s}{T_f + T_s} = 1 - \alpha$,

Obviously, if $\alpha < 1, 1 - \alpha > 1$ is established, incomplete differential algorithm can be obtained.

$$u_D(k) = K_D(1-\alpha)(error(k) - error(k-1)) + \alpha u_D(k-1)$$

(12)

Medium, $K_D = k_p \bullet T_D / T_s$ 。

The above k_p ratios are proportional coefficients, and T_I and T_D are integral time constant and differential time constant, respectively. T_f is the filter coefficient.

D. *Design and Simulation of PID controller for magnetic bearing based on LabVIEW*

The block diagram of the magnetic bearing control system is shown in the diagram.

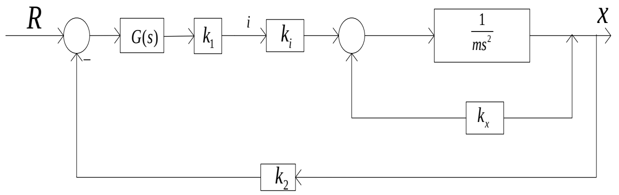
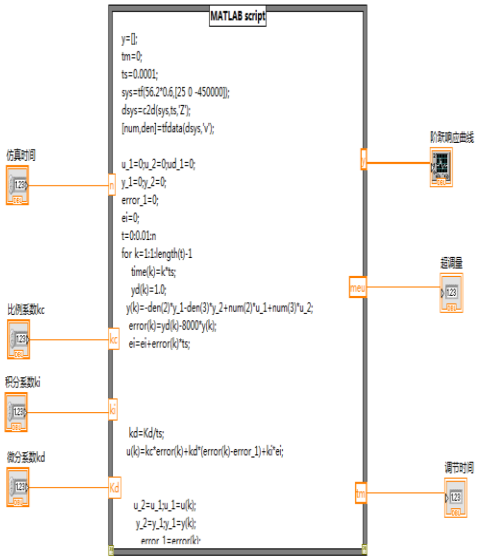


Figure 3 block diagram of magnetic bearing control system

To achieve PID control, the PID parameter is $k_p = 6.5$, $k_I = 235$, k_D =0.036, the $k_1 = 0.6$, $k_2 = 8000$ simulation time is 0.15s, the front panel of the LabVIEW based magnetic levitation control system and the simulation program panel are shown as shown.

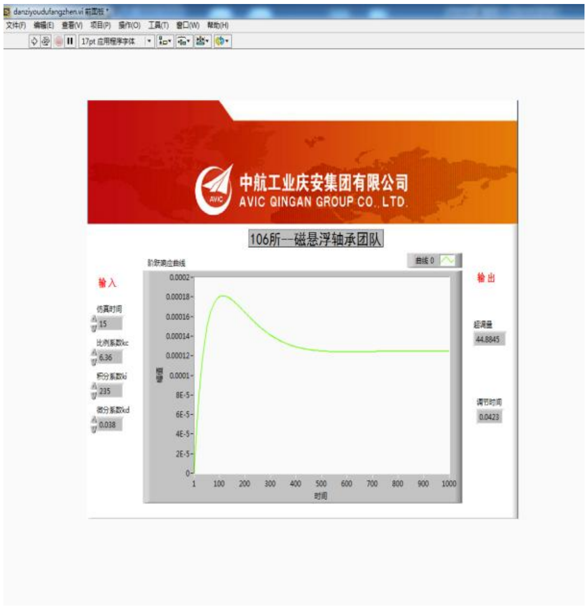
Figure 4 Labview front panel



```
y=[];
tm=0;
ts=0.0001;
sys=tf(56.2*0.6,[25 0 -450000]);
dsys=c2d(sys,ts,'Z');
[num,den]=tfdata(dsys,'v');

u_1=0;u_2=0;ud_1=0;
y_1=0;y_2=0;
error_1=0;
ei=0;
t=0:0.01:n
for k=1:1:length(t)-1
    time(k)=k*ts;
    yd(k)=1.0;
  y(k)=-den(2)*y_1-den(3)*y_2+num(2)*u_1+num(3)*u_2;
   error(k)=yd(k)-8000*y(k);
   ei=ei+error(k)*ts;



   kd=Kd/ts;
  u(k)=kc*error(k)+kd*(error(k)-error_1)+ki*ei;


     u_2=u_1;u_1=u(k);
      y_2=y_1;y_1=y(k);
```

Figure 5 simulation program panel

The simulation results after the input parameters are shown in the following diagram.



仿真时间 15
比例系数kc 6.36
积分系数ki 235
微分系数kd 0.038
超调量 44.8845
调节时间 0.0423

Figure 6 simulation results of magnetic bearings

The system has a short rise time and fast response speed.

E. *Conclusion*

In this paper, the method of mixed programming with two programming languages of MATLAB and LabVIEW is proposed, and the technical characteristics and design method of MATLAB Scrip node are used to simulate the magnetic bearing control system. Through the basic principle and Simulation Research of PID controller, it is shown that PID can stabilize the magnetic bearing effectively. NI LabVIEW platform, which is easy to modify with parameters and convenient for engineering application, is developed, which greatly improves the engineering efficiency.

REFERENCES

[1] Magnetic bearing -- theory, design and application of rotating machinery [M]. Xu Yang, Zhang Kai, Zhao Lei translate.

[2] LabVIEW programming and application [M]., Yang Leping, Li Haitao, Xiao Xiangsheng and other edited.

[3] Hautus MLJ, Heymann. M Linear feedback decoupling-transfer function analysis. IEEE TRANS. AUTOM.CONTR.,vol.AC-28,pp.823-832,1983

[4] Chen Shuzhong. The condition of transfer function for system decoupling. Control theory and application, 1994,11 (2): 203-206

[5] Liu Jinkun. Advanced PID control MATLAB simulation [M]. Beijing: Electronics Industry Press.