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SpeedControlofPermanentMagneticLinearSynchronousMotorbasedonExtendedStateObserver

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Abstract:*Permanent Magnet Linear Synchronous Motor (PMLSM) is a multivariable system of nonlinear and strong coupling. It is sensitive to external disturbance and parameter variations, so the anti-jammingcapability of the control system has higher requirements. This article based on the mathematical model of PMLSM, in combination traditional active disturbance rejection control (ADRC)with feedback control，proposed an improved ADRC control algorithm for the PMLSM speed control system. A model of PMLSM speed control system is established in the Matlab/simulink simulation environment. The simulation result shows that compared with classical PID and traditional ADRC controller，this method has good performance of disturbance rejection.*

Key words*:PMLSM；The modified ADRC；PID；Traditional ADRC; Speed control*

I. Introduction

Permanent Magnet Linear Synchronous Motor has advantages of high efficiency、high power density and low rotational inertia. In modern servo system, especially in small capacity and high performance servo drive field, the Ac servo system by PMLSM gradually developed into the mainstream of the market [1]. However，in the PMLSM speed regulation system, the control performance will become worse when a load is added suddenly or some disturbances existing in the load[2].

In order to improve the control performance of PMLSM system, scholars research for control algorithm for long years. A new control scheme which was designed by a technique of ADRC was represent in this paper. The load mutation and load disturbance were all contributed to an unknown disturbance and ADRC is used for system estimation, compensation and control. In general system, often use PID control technology to realize q axis current control, speed loop adopts ADRC control technology (named ADRC+PID), this kind of design can not completely eliminate the dynamic coupling of shaft current and overshoot [3]. In order to alleviate the influence of current coupling and enhance the system stability, the speed control of PMLSM by the modified ADRC (named FADRC) is analyzed in this paper. The simulation result shows that compared with the traditional ADRC+PID and PID control system; this method has less overshoot and good performance of disturbance rejection.

II. Mathematic model of PMLSM

Under the dynamic synchronous movement reference of $d-q$,use $x=[i_d\, i_q\, v]^T$ as state variable，$u=[u_d\, u_q\, F_\xi]^T$ as input variable，we can establish nonlinear dynamic performance model of PMLSM as follow:

$$\begin{cases} \dfrac{\mathrm{d}i_d}{\mathrm{d}t} = -\dfrac{R_s}{L_d} i_d + \dfrac{\pi L_q}{\tau L_d} + \dfrac{U_d}{L_d} \\ \dfrac{\mathrm{d}i_q}{\mathrm{d}t} = -\dfrac{Rs}{L_q} i_q - \dfrac{\pi L_d}{\tau L_d} i_d v - \dfrac{\pi \lambda_{pm}}{\tau L_q} v + \dfrac{U_q}{L_q} \\ F_e = \dfrac{3P\pi}{2\tau}[\lambda_{pm} i_q + (L_d - L_q) i_d i_q] \qquad (1) \\ \dfrac{\mathrm{d}v}{\mathrm{d}t} = \dfrac{1}{m}(F_e - F_l - Bv) \end{cases}$$

Here, u_d , u_q are voltage in axis d,q ; i_d , i_q are current in axis d,q ; V_s is r linear velocity; R_s is phase resistance; L_d, L_q is inductance; λ_{pm} is flux linkage; τ is polar distance; F_e is electromagnetic force; F_l is resistance of system; m is mass of motor; B isviscous friction factor; p is number of pole pairs.

Eq(1) mainly consider two types disturbance , load resistance and viscous friction , but there are other forms of disturbance in the actual system, such as frictional friction, wind resistance, Tooth groove thrust, ripple friction, etc[4]. Tooth groove thrust and ripple thrust mainly suppress from the angle of motor design; wind resistance perturbation is neglected, regard the static friction force and sliding friction as a comprehensive friction disturbance, the expression is：

$$f(v)= f_c sgn(v)+(f_s- f_c)e^{-(v/v_s)^2} sgn(v) \qquad (2)$$

Here, $f(v)$ is comprehensive friction; $f_{(c)}$, $f_{(s)}$ are kinetic and static friction force.

III. The design of ADRC

Traditional Active Disturbance Rejection Controller mainly consist of discrete Tracking Differentiato（TD），Extended State Observer（ESO）and Nonlinear State Error Feedback control law（NLSEF）, In this paper, in combination the feedback control with traditional ADRC system. Realize PMLSM position and speed control system based on the improved ADRC. Fig.2 shows the structure of improved ADRC：

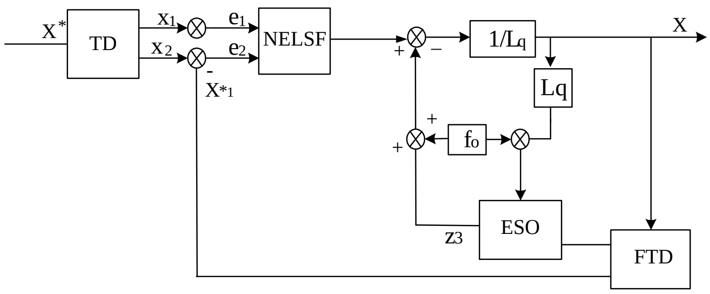

Fig.1 Structure of ADRC

$$f_0=-\frac{3\pi^2 n_p \psi^2{}_{pm}}{2m\tau^2 L_q}v \quad (3)$$

Tracking Differentiator of Feedback channel mainly use smoothing function and differential function of TD, to filter the output measured value of the controlled object , at the same time order differential signal is obtained ,then obtain the state variables of the controlled object. That is ： $x_1^* \to y = x_1, x_2^* \to y^1 = x_2, \cdots\cdots, x_n^* \to y^{n-1} = x_n$

To compensate phase lag after filtering operation, joined the differential prediction compensation algorithm in FTD, the expression is:

$$\begin{cases} x_1(k+1)=v_1(k)+hx_2(k) \\ x_2(k+1)=x_2(k)+hfh^* \\ fh^* = hfhan(x1(k)\text{-}v^*(k),x_2(k),r_0,h_0) \\ v_1^*(k)=x_1(k)+\eta hx_2(k) \\ v_2^*(k)=x_2(k) \end{cases} \qquad (4)$$

Where, η is differential prediction step length factor.

Under the condition of without changing the subsidence ratio of system and in the range of the controlled object, TD can reduce the initial error. In fact, the Actual system have inertia, the system output only can range from zero slowly began to change, so if directly use the error to calculate the control quantity, will easy to cause the system overshoot [5]. According the control object signal to arrange a suitable transition, then let actual behavior of the system tracking this transition process to achieve control object, so solve the contradiction between system overshoot and quick response.

The form of TD is described as follows.

$$\begin{cases} fh=fhan(v_1(k)\text{-}v(k),v_2(k),r,h_0) \\ v_1(k+1)=v_1(k)+hv_2(k) \\ v_2(k+1)=v_2(k)+hfh \\ e=z_1(k)\text{-}y(k) \end{cases} \qquad (5)$$

Here， h_0 is tracking differentiator filtering factor； h is integral step； k is sampling time number k ；

$k+1$ is sampling time number $k+1$; r determine the speed of tracking.
The form of ESO is expressed as：

$$\begin{cases} e=z_1(k)-y(k) \\ z_1(k+1)=z_1(k)+h(z_2-\beta_{01}e) \\ z_2(k+1)=z_2(k)+h(z_3(k)-\beta_{02}f_e+b_0u) \\ z_3(k+1)=z_3(k)+h(-\beta_{03}f_{e1}) \\ f_e=fal(e,0.5,\delta) \\ f_{e1}=fal(e,0.25,\delta) \end{cases} \quad (6)$$

Where, δ isthe linear section of the interval length， $z_3(k)$ is the estimate of extended state $x_3(k)$， if the parameter b is known，control variable can be take into:

$$u=\frac{u_0-z_3(t)}{b} \quad (7)$$

The second order nonlinear system： $\ddot{y}=f(y,\dot{y},d(t),t)+bu$ become into a second order linear integrator series control system，as：

$$\ddot{y}=f(y,\dot{y},d(t),t)+b\frac{u_0-z_3}{b} \quad (8)$$

The form of NELSF is expressed as：

$$\begin{cases} e_1=v_1-z_1; e_2=v_2-z_2 \\ u_0=b_1 fal(e_1,a_1,\delta)+b_2 fal(e_2,a_2,\delta) \\ u=(u_0-z_3)/b_0 \end{cases} \quad (9)$$

Here, b_1,b_2 are the adjustable parameters ; a_1 ,a_2 meet the condition $0<a_1<a_2<1$， the expression of nonlinear function $fal(e,a,\delta)$ is same with Eq(8); δ is same with Eq（9）. If select parameter b_1,b_2 properly，we can achieve the output of system tracking target value.

IV. Modified ADRC control system of PMLSM

It can be seen from Eq (1), system need three integrator from input control to the output control variable. In order to simplify the design, transform the PMLSM control system into a first order system with a second order system, thus using the immunity control of cascade system to control PMLSM. The current loop adopt first-order ADRC, speed loop adopts second order ADRC, put $i_d=0$ into mathematical model of PMLSM can get：

$$\begin{cases} \frac{\mathrm{d}i_q}{\mathrm{d}t}=-\frac{R}{L_q}i_q-\frac{\pi\psi_{pm}}{\tau L_q}v+\frac{1}{L_q}u_q \\ \frac{\mathrm{d}v}{\mathrm{d}t}=\frac{3\pi n_p\psi_{pm}}{2m\tau}i_q-\frac{F_l}{m} \end{cases} \quad (10)$$

put the first formula into second, Eq(10) becomes

$$\frac{\mathrm{d}^2v}{\mathrm{d}t^2}=-\frac{3\pi^2n_p\psi^2{}_{pm}}{2m\tau^2L_q}v-\frac{3\pi^2n_pR\psi_{pm}}{2m\tau L_q}i_q-\frac{\dot{F_l}}{m}+\frac{3\pi n_p\psi_{pm}}{2m\tau L_q}u_q \quad (11)$$

The first item is internal disturbance of speed dynamic process, the second item is external disturbances of current in axis q against speed dynamic process, and the third is comprehensive function for the system's external disturbance. In the ideal action, ESO can observe unknown disturbance of system through the input and output speed of system，take control variable：

$$u_q=\frac{2m\tau L_q(-\frac{3\pi^2n_p\psi^2{}_{pm}}{2m\tau^2L_q}v-\frac{3\pi^2n_pR\psi_{pm}}{2m\tau L_q}i_q-\frac{\dot{F_l}}{m})}{3\pi n_p\psi_{pm}} \quad (12)$$

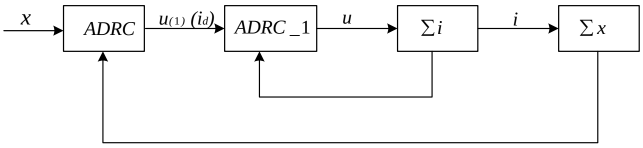

Fig.2 Structure of speed ADRC control

As shown in the above permanent magnet synchronous linear motor speed ADRC system contains the speed loop and current loop, the current inner ring still adopt the decoupling control of ADRC to realize vector control.

V. The simulation results

Due to the mission of the first-order ADRC is to track the change of the control target as soon as possible, so cancel arranging transition part of current. The control system of PMLSM adopts PID、ADRC+PID and FADRC to simulate. The given speed is 1 and added 20 load at 0.1s; Fig (3) shows that adopting the FADRC speed control system can be quickly arrived the given speed without overshoot and fluctuation.

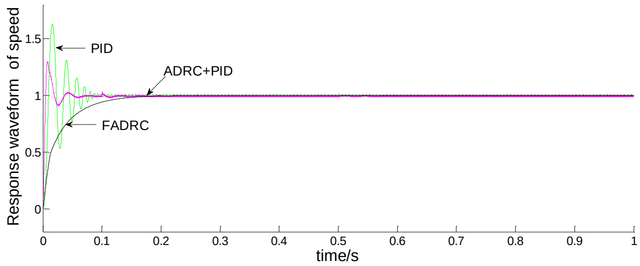

Fig.3 Response waveform of speed

The system parameters as follows: m =2.875, R_s =2.8, $f_{(c)}$ =40, $f_{(s)}$ =50, $L_d = L_q$ =8.5mh, B =0.175, P =3, τ =32mm

VI. Conclusion

This paper base on vector control method, aim at permanent magnet synchronous linear motor has characteristics as strong coupling, nonlinear, multivariable. On the basis of PMLSM control system and combined with the improved algorithm of ADRC. The simulation result shows that this design has less overshoot and good performance of disturbance rejection, the extended state observer in ADRC can effectively observation on PMLSM with the sum of the disturbance and its speed, nonlinear controller to corresponding compensation of disturbances, and according to speed feedback error computing control quantity in real-time. Comparing speed control system of the improved ADRC with the traditional ADRC and PID control, it has good performance of disturbance rejection.

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References:

[1]. Ying Shrieking. Design and Implementation of a High Performance PMLSM Drives Using DSP Chip. IEEE Transactions on Industrial Electronics, 2008, 55 (3):1341-1351.
[2]. Lim K C, Woo J K, KangG H. Detent force minimization techniques in Permanent magnet linear Synchronous motors.IEEE Transactions on Magnetizes, 2002, 38(2): 1157 一 1160.
[3]. Zhu Y W, Lee S G, Chung K S, et al. Investigation of auxiliary Poles design criteria on reduction of end effect of detent force for PMLSM. IEEE Transactions on Magnetizes, 2009,45(6):2863—2866.
Zhao S, GAO Z Q. An Active Disturbance Rejection Based approach to Vibration Suppression in two-Inertia Systems. Proceedings of the Armenian Control Conferenee,Baltimore,2010,PP.1520—1525.