# High Precision Servo System reference input learning PMSM

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**Abstract:** For high-precision position servo system has run repeatedly on the properties of iterative learning control (iterative learning control, ILC), you can get totally theoretical position on track. But in fact, many of the servo drive usually consists of commercial products, and these products can not be commercialized or inconvenience reconfigured. The traditional iterative learning control for the embedded structure of the control system must be redesigned to use, it is not conducive to promote the use of iterative learning control. For this reason, some scholars have proposed in the literature reference cascade iterative learning control, modify the reference signal by iterative learning, repeatedly improved control system performance, without changing the existing controller structure, simple. This article will focus PMSM position servo system with high-precision operational characteristics duplicate analyzes the limitations of traditional control methods proposed learning control based on the reference input iterator precision control strategy, given controller structure, and derive convergence condition simulation and experimental Research.

## The controller structure and convergence analysis

Scholars from various countries try to apply to a variety of advanced control theory PMSM position servo system: the literature application mode variable structure control, proper design of the sliding surface servo system and control law, the position of speed regulator integrated design for the system outer regulator; was designed based on ADRC PMSM position servo system to achieve fast response with no overshoot, high steady-state accuracy of location tracking of the load, moment of inertia and stator resistance changes with a robustness[1-2]; literature proposed a fuzzy predictive control algorithm of PMSM position servo system is robust and real-time to achieve a good static and dynamic performance; the literature with Backstepping design method for permanent magnet synchronous motor position control system can get good tracking results, and its rapid exponential filter characteristics of the tracking error converge to zero, with good position servo control characteristics.

For PMSM position servo system has run repeatedly characteristics can position reference signal by iterative learning, in order to improve their position tracking accuracy, cascaded iterative learning block diagram shown in Figure 1. Where in the frame are "current period" for the traditional PMSM 3 closed-loop position servo system structure shown in Figure 1; dashed box "previous cycle" as part of the iterative learning the position of the reference signal, to improve tracking performance, Iterative Learning open-loop P-type learning law. Since the whole system and not on the traditional 3 closed loop position servo system changes within the "current period" can be commercialized servo controller, to facilitate the development of the entire servo system.

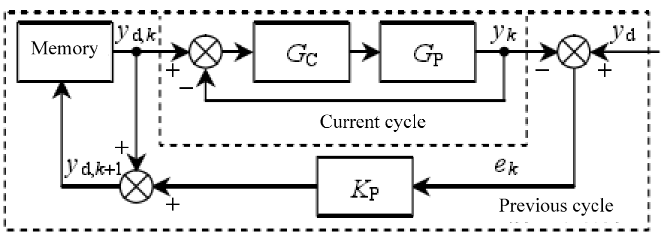



Fig. 4 Block diagram of controller with ILC

From Fig. 1, we have

$$\begin{cases} Y_{\mathrm{k}}(s) = \Phi(s) Y_{d,k}(s) \\ E_k(s) = Y_d(s) - Y_k(s) \\ Y_{d,k+1}(s) + K_p E_k(s) \\ Y_{d,1}(s) = Y_d(s) \end{cases} \tag{1}$$

Where: $Y_d(s)$ desired reference cycle signal; $Y_{d,k+1}(s)$ for the study by the k th corrected reference signal, hence the output $Y_{d,1}(s) = Y_d(s)$ ,$Y_{\mathrm{k}}(s)$ of the system is running after the k th; $E_k(s)$ to $K_p$ for the open-loop learning error P-type iterative learning law gain.
thus the convergence condition can be derived as

$$\left\| \frac{E_k}{E_{k-1}} \right\| = \left\| 1 - \Phi K_p \right\| = \left\| 1 - \frac{G_c G_p K_p}{1 + G_c G_p} \right\| < 1 \tag{2}$$

**The simulation results and analysis**

As the permanent magnet synchronous motor position servo system has a wide current loop bandwidth, for simplicity, that the actual current value can be ideal for tracking a given value, the servo system block diagram can be simplified as shown in Figure 5. Based on the above control strategy in Matlab/Simulink to establish a system simulation model, system simulation structure shown in Figure 4, the figure in the "current period" PMSM position servo system is a simplified block diagram is shown in Figure 2, set the desired location $Y_d(t) = 10\sin(2t), t \in [0, \pi], Kp$ trajectories take a convergence condition is satisfied formula (6).

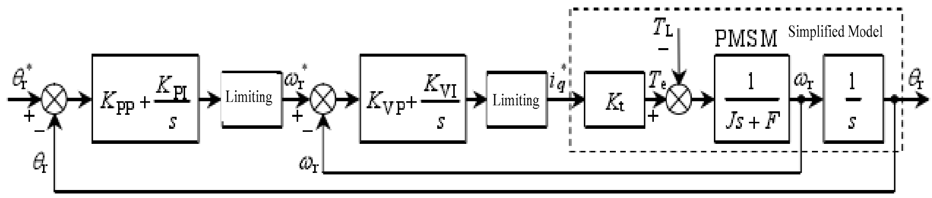
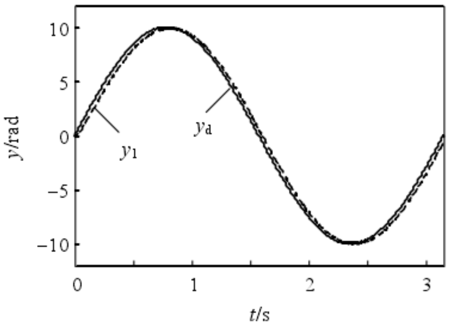



Fig. 2 Simplified block diagram of PMSM position servo system

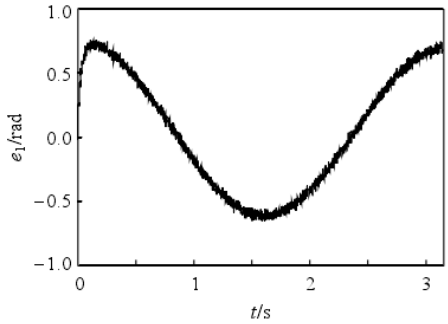
Not learning (1st run system) control results shown in Figure 2. There is a big visible position tracking error, maximum error is 0.75rad, over the entire time interval, the integral absolute error reaches 1.31rads. In fact, regardless of how the controller parameter adjustment, these errors always present, which verify the theoretical analysis of the foregoing.

System 10 7 effect correction by iterative learning control after the reference input. The figure shows the position of the tracking accuracy is significantly improved, the maximum error occur at the initial moment, about 0.1rad, the remaining time is much less than this value. Over the entire time interval, the integral absolute error is only 0.051rad  s. After the iterative learning, reference input AA has non original standard sine function.

For a high-precision position servo system of permanent magnet synchronous motors, it is difficult to obtain good tracking accuracy with traditional control methods because of the controller's bandwidth and performance limitations. Based on such a position servo system running repeatedly, a cascaded iterative learning control method was proposed to modify the reference input signal, through which to make the actual position of the servo system to track the original expected input. The controller structure was given, and the convergence condition was derived. Simulation and experimental results prove the effectiveness of the proposed method. The method has the following characteristics: Firstly, compared with the traditional controller, the method can greatly improve the tracking accuracy; Secondly, the controller design is simple and with small amount of calculations and also without changes to the original controller, so that the development of servo products is more convenient; Thirdly, under the circumstance of meeting the convergence condition, the method has strong robustness and is not sensitive to motor parameters.

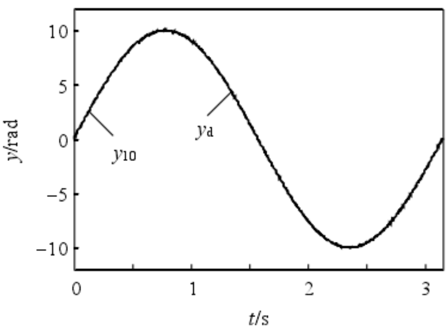



(a) track curve

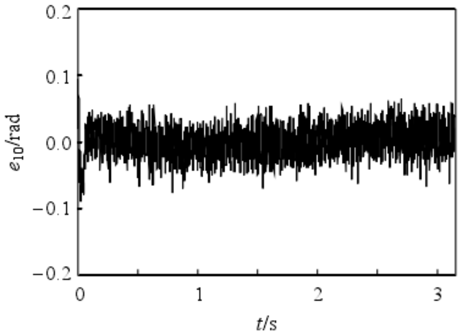



(b) tracking error

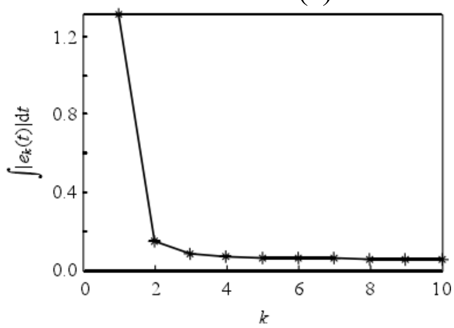
Fig. 3 Simulation results without ILC



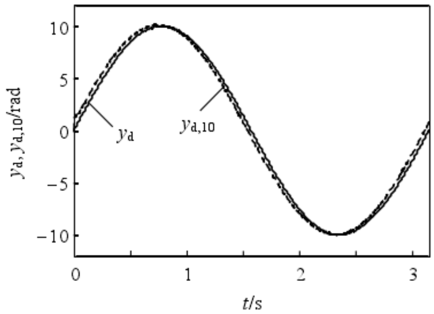

(a) track curve




(b) tracking error




(c) iteration k axis error




(d) reference input

Fig. 4 Simulation results with ILC and k=10

## Experimental results and analysis

In order to verify the feasibility of the control strategy designed experiment system as shown in Fig 5. Wherein the central processing unit with DSPTMS320F2812; driving circuit using IR's latest IGBT Driver IC IR21141S; inverter unit consisting of full-bridge IGBT selection; between the control circuit and a driver circuit coupled with ADI's high-speed magnetic isolation; system by rotating transformer position and speed measurement, the decoder uses AD2S1210,12 bit resolution at maximum track speed 60000r / min, to meet the system requirements of high-speed motor; current measurement with high reliability, high-precision monolithic Hall ICACS758. Real experimental system shown in Fig 6.

Location desired trajectory remains yd (t) 10sin (2t), since the actual system unavoidable presence of measurement noise, in order to ensure the accuracy of the tracking system Diego, to improve the servo performance provides an effective method.

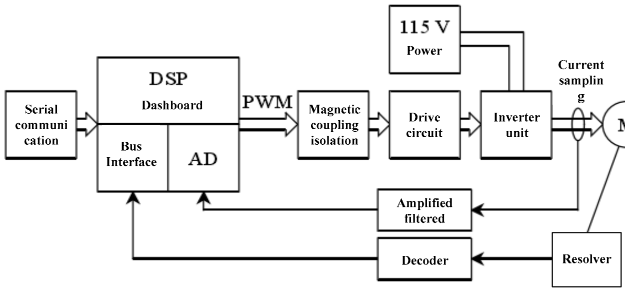



Fig. 5 Experimental system diagram

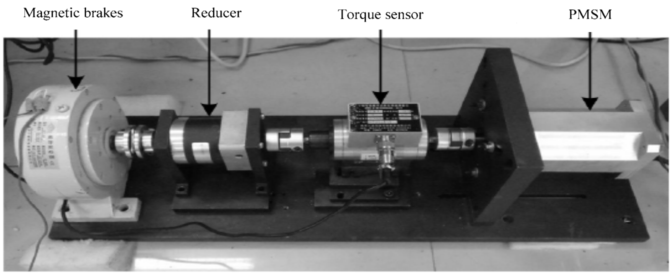



Fig. 6 Photograph of the experimental system

**Based on the limitations of traditional control methods**

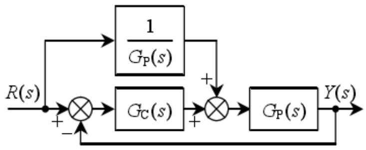



Fig. 7 Block diagram of position loop with feedback-feed forward control structure

Seen from Figure 7, full recovery of input output, improve the performance of high precision servo tracking system. But the disadvantage is the need to know the exact mathematical model of controlled object, which is generally difficult to achieve, but also need to adjust the structure of the original closed-loop control system, thus making the feedback - feed forward control method to control the effect of greatly reduced, and when the closed-loop system is non-minimum when phase systems, this method cannot be applied.

Always exists between the actual position and the reference signal output deviation, namely the traditional position controller, in theory, can not ensure high accuracy location tracking. In addition, the speed loop and current loop also has the same problem, which is exacerbated by the tracking performance of the servo system.

Order to solve the conventional PID position controller own nature defects, you can use feed forward compensation [6-8]. Classical control theory feed forward control design is based on a composite control thought, so that the integrated feed forward transfer function of the closed loop system is 1, in order to achieve full recovery of input output, based on the feedback - Position loop feed forward control structure.

## Conclusion

Permanent magnet synchronous motors High Precision Servo System with duplicate operating characteristics, we propose using the cascade method of iterative learning modify the reference input to improve the position servo accuracy. In the case of the original servo system performance is determined by iterative amendments to the reference input to obtain the actual position of approaching originally expected input. The simulation and experimental results demonstrate that the control method has the following characteristics: Compared with traditional controllers, can greatly improve the accuracy of servo control; simple design, small amount of calculation, easy to commercialization with the existing servo controller system integration, can not increase under the premise of the original controller changes to the system performance; 3) in meeting the convergence of iterative learning conditions, insensitive to motor parameters, robustness. Position controller, speed controller and current controller are commonly used PID structure, speed loop and current loop bandwidth is the difference compared with the position loop magnitude, it is assumed that the speed loop and current loop can achieve the desired track, just consider the location Ring. Always exists between the actual position and the reference signal output deviation, namely the traditional position controller, in theory, can not ensure high accuracy location tracking. In addition, the speed loop and current loop also has the same problem, which is exacerbated by the tracking performance of the servo system.

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