Research on thrust fluctuation suppression and control algorithm of permanent magnet linear synchro

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Abstract: Compared with the conventional rotary motor, the permanent magnet linear synchronous motor (PMLSM) has the advantages of simple structure, large thrust and good fast response. However, due to the linear motor ripple disturbance and positioning force changes will cause thrust fluctuations, but also affected by the end effect, slotting force and load changes, system parameter drift, nonlinear friction force, etc., resulting in poor system controllability, which directly affects the positioning and trajectory tracking accuracy of the linear motor, by observing the thrust fluctuations of the permanent magnet linear synchronous motor, By using prediction function and fuzzy control algorithm, the thrust fluctuation suppression method based on fuzzy prediction function control is established, and the improved prediction function fuzzy controller is constructed. According to the deviation and deviation change rate of the system, the parameters of the fuzzy controller are optimized and adjusted online by using the proportional coefficient, so as to improve the comprehensive performance of the linear motor servo system, and provide the theoretical basis and technical approach for realizing the high-performance linear motion system.

Key words: permanent magnet linear synchronous motor (PMLSM); Thrust fluctuation; Prediction function

Foreword:

A typical representative of high performance linear motion system is linear feed servo system of high speed CNC machine tool. The linear motor is used to drive each mechanism directly, which simplifies the system structure and effectively improves the performance of the linear feed system. But the coupling between each mechanism, the load force, the external disturbing force and so on increase the difficulty of the design of the motion brake. The predictive function control algorithm has the characteristics of simple algorithm, small computation and good tracking performance. Different from the traditional model predictive control, predictive function control is a new predictive control method based on the principle of model predictive control, which is developed to meet the need of fast process.

In this paper, theoretical analysis, numerical simulation, innovative optimization and experimental research are carried out to solve the common key problems such as disturbance observation and compensation and thrust fluctuation suppression in the high-performance linear motion system of linear motor. Based on the theory of predictive function control algorithm, the “intractable” thrust fluctuation of linear motor is taken as the research object. The causes of linear motor thrust fluctuation are extracted to be studied and solved, and the dynamic control of parallel CNC machine tool servo system is used as the platform for simulation and verification, which lays a solid foundation for the high-speed and high-precision application of linear motor. By means of theoretical analysis, numerical simulation, model establishment and simulation verification, the thrust fluctuation of linear motor is studied. The linear feed system of CNC machine tool is used as the experimental platform to verify the linear motor thrust fluctuation motion control theory and method based on predictive function control, which promotes the development of linear motor control technology and its final application in high-performance linear motion system.

I. The research content

1. Observation of linear motor thrust fluctuation based on interference observer and fuzzy controller

High precision under the premise of high speed is an important task of linear motor motion control system and the key goal of its development. Linear motor adopts direct drive mode, the lack of intermediate transmission link damping, buffering and other functions, resulting in thrust fluctuations directly transmitted to the motor itself, so that the motor control performance, operating state is seriously affected, limiting its application in the field of high precision and high speed. In the linear servo system, the characteristics of the large thrust fluctuation of the permanent magnet linear synchronous motor seriously affect the stability and positioning accuracy of its control system at low speed, and the system will also produce vibration and noise. In view of the characteristics of the linear motor thrust fluctuation, the disturbance observer is used to observe and properly compensate the various disturbance effects in the system, and the fuzzy controller is combined to weaken the necessity of establishing the nonlinear accurate model, so as to realize the accurate observation and full study of the linear motor thrust fluctuation.

2. Linear motor thrust fluctuation mechanism analysis and the establishment of nonlinear dynamic fuzzy mathematical model

In the linear motor servo system, the thrust fluctuation is the unique nonlinear interference brought by its structural characteristics, which is the most direct and main factor causing the vibration and noise of the linear motor servo system. Thrust ripple, slotted effect and end effect are the main causes of thrust fluctuation in linear motor servo system. Among them, the thrust ripple is caused by the interaction between stator and rotor harmonic magnetic field, which results in the non-linearity of the moving armature back electromotive force and the phase current input by the inverter. Coreless linear motor technology can be used to eliminate the coreless effect, which is caused by the interaction between the coreless core structure and the stator magnetic field. The end effect is the most important factor causing the thrust fluctuation of linear motor, because the magnetic flux distribution of the broken core is different from the middle magnetic flux distribution, resulting in serious distortion at the end of the permanent magnet field after the armature winding is energized. Therefore, the thrust

fluctuation model mainly caused by thrust ripple and end effect will be deeply studied, and the nonlinear dynamic fuzzy mathematical model will be established.

3. The realization of linear motor thrust fluctuation control method based on predictive control function and fuzzy control algorithm

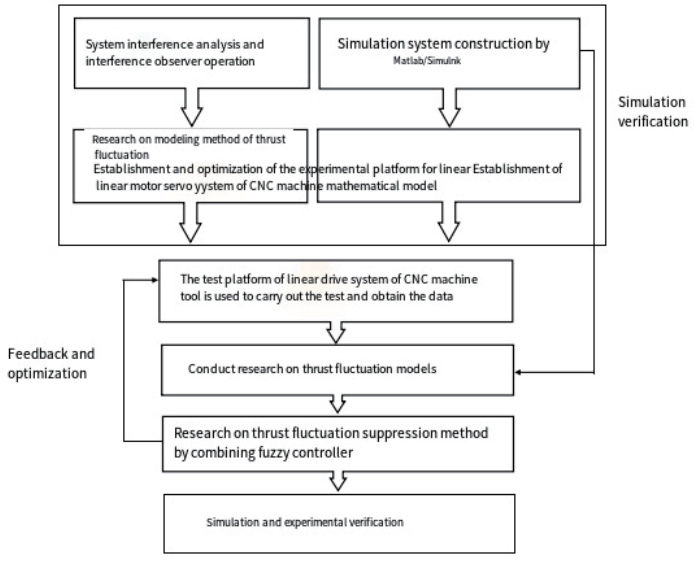
The predictive function control method has the characteristics of simple algorithm, small amount of calculation, fast dynamic response speed and high precision, and is first applied to the fast control system of industrial robot tracking and target tracking in the military field. The predictive function control has low requirements on the mathematical model of the controlled object, and the generated control input is more regular, and can effectively reduce the calculation amount of the algorithm. And it has good robustness. Fuzzy control algorithm belongs to the category of intelligent control, is a nonlinear control method, it does not depend on the mathematical model of the object, has the function of parameter self-adjustment, especially suitable for nonlinear system. In order to improve the robustness of predictive function control, combining predictive function control and fuzzy control, a new control method of thrust fluctuation of permanent magnet linear synchronous motor based on fuzzy predictive function control is tried. It is intended to combine predictive function control and fuzzy control to jointly control the servo system of permanent magnet linear synchronous motor, and according to the speed deviation and deviation change rate of the control system, the parameters of the fuzzy controller are optimized and adjusted online according to the proportional coefficient, so as to greatly reduce the thrust fluctuation of the linear motor and improve its thrust characteristics.

II. The technical route

Predictive function control retains the advantages of predictive control online rolling optimization and constraint processing, and has the characteristics of fast tracking, good robustness, high control degree, and small real-time calculation, which is suitable for high-speed control of servo system. The thrust fluctuation control strategy of linear motor servo system is studied by the combination of interference observer and predictive function control. In the system dynamic characteristics analysis, control algorithm simulation and experimental verification research, the use of large general mathematical simulation software MatLab/Simulink, the establishment of a reasonable system disturbance model and control algorithm module, it can be more accurate to get the system dynamic simulation results and control algorithm research. CNC machine tool linear servo system is a typical representative of the motion control system, using linear motor driven CNC machine tool linear servo system as the experimental platform, the linear motor control of all kinds of high-performance linear motion system when the disturbance observation and suppression of the key problems are carried out experimental research.

According to the formation principle of thrust fluctuation, a fuzzy model of thrust fluctuation based on prediction function is established, focusing on ripple disturbance and positioning force change, and a fuzzy controller is used to study thrust fluctuation suppression.

The specific technical route is shown in the figure:



Thrust fluctuation suppression research specific technical roadmap

The thrust fluctuation control method of linear motor based on disturbance observer and predictive function control algorithm is studied, and the influence of dynamic uncertain disturbance factors such as positioning force and ripple disturbance of the system is analyzed and observed, and the thrust fluctuation suppression model based on predictive function is established.

The thrust control method of linear motor based on prediction function algorithm is analyzed and proposed. Through three steps of prediction function model establishment, rolling optimization and feedback correction, combined with the online compensation function of fuzzy control algorithm, the commutation thrust fluctuation of linear motor is suppressed, so as to achieve smooth thrust characteristics during commutation under various working conditions, and effectively track the change of given thrust instructions. To achieve the smooth dynamic performance of the linear motor.

III. Research strategy

1. Analyze thrust fluctuations

First, the advanced numerical control technology of Jiangsu Province university key laboratory of existing mature hardware conditions to build a test platform. The thrust fluctuation of linear motor servo system and the influence degree of each disturbance in low speed and commutation operation of linear motor are analyzed. Observe the speed change and deviation rate, according to the characteristics of thrust fluctuation and load force, analyze and model the speed change and deviation rate by observing it, and identify the model parameters by using the measured data. Among them, the commonly used mathematical model of linear motor thrust fluctuation is:

$$f_r(x) = \sum_{i=1}^{\infty} A_i \sin(\omega_i x + \varphi_i)$$

Where, Ai is the amplitude of thrust fluctuation, i is the angular velocity with displacement as a variable, i is the phase Angle, all of which are related to the structure of the linear motor, and x is the moving displacement.

2. Modify the control parameters

Similar to the mechanism of commutation torque fluctuation of rotary brushless DC motor, linear motor commutation thrust fluctuation is caused by current fluctuation during commutation. The prediction function algorithm is proposed to establish an improved thrust fluctuation model, and the fuzzy controller's online correction function is used to control the thrust of the linear motor. Based on the prediction function algorithm, the improved thrust fluctuation model is established, focusing on suppressing the commutation thrust fluctuation, so that the linear motor can obtain smooth thrust characteristics and better track the change of the given thrust command. The linear motor thrust control system based on prediction function algorithm and fuzzy controller is shown in Figure 2.

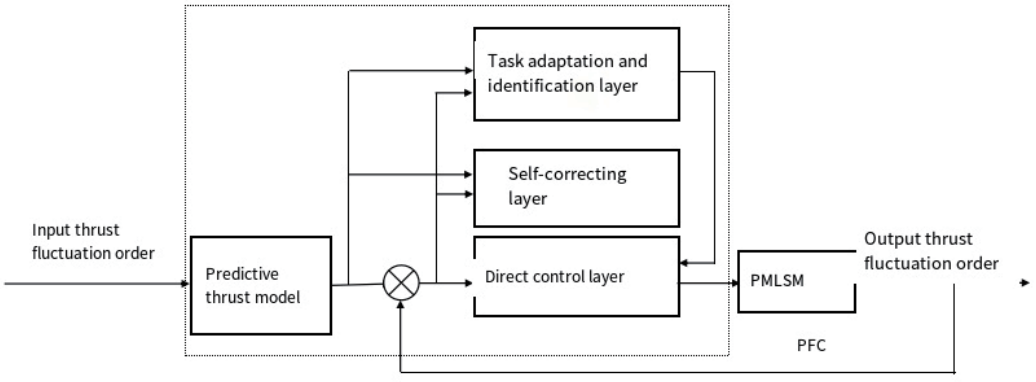


FIG. 2 Linear motor thrust fluctuation control system based on prediction function and fuzzy controller

3. Suppress system dynamics

Because the transmission mechanism of linear feed system is simplified, the dynamic uncertain disturbance factors of the system increase and directly affect the linear motor. And the system thrust fluctuation, load mutation, friction, coupling force and external interference and other uncertain disturbance will seriously affect the system's motion performance and positioning accuracy, and even cause oscillation, resulting in system instability. Especially in the feed system with high speed and high precision, the coupling effect between the components is very obvious and constantly changes, so the robustness of the control algorithm is required to be higher. In addition, the actual system usually contains more nonlinear and unknown dynamic links, which presents a difficult problem for a class of control algorithms based on system models. By effectively observing and suppressing the influence of system dynamic uncertainty perturbations, the key scientific problem of control performance degradation caused by modeling errors is solved.

4. Verify the suppression results

The above research content first establishes a model in MatLab/Simulink for simulation research, and then carries out experimental verification with the linear drive test system of CNC machine tools. Using the control method based on kinematics to study the linear electric drive system, that is, it is assumed that the linear motor of the linear electric drive system is independent of each other, through the control of each linear motor to track their own control objectives, to achieve the expected trajectory, speed and posture of the moving platform. This method is simple and easy to operate, but in practical applications, multiple linear motors are not independent of each other, but coupled with each other through the motion platform, and the constantly changing load force is used for each linear motor. The control method based on kinematics can effectively test the anti-disturbance performance and thrust fluctuation control ability of the motion control algorithm of the linear motor.

Epilogue:

The new thrust wave suppression algorithm is applied to the linear motor servo system of CNC machine tool, and the dynamic characteristics of linear motor and linear servo system of CNC machine tool are studied by theoretical analysis and numerical simulation.

The on-line real-time control test platform meeting the research requirements is built, and the fuzzy controller is tried to implement rolling optimization and on-line correction. Improve the system's ability to suppress disturbance, improve the dynamic performance control ability of permanent magnet linear synchronous motor, and lay the foundation for CNC machine tool linear feed system to achieve high and low speed control, high precision trajectory tracking and smooth thrust control.

Through the thrust fluctuation observation, the predictive function control and interference observer are combined to improve and optimize the permanent magnet linear synchronous motor thrust fluctuation formation mechanism and suppression method are studied, a mathematical model based on predictive function control algorithm is established, and a new algorithm of improved predictive function fuzzy control is proposed to improve the comprehensive control performance of the system.

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