Research on Control Strategy of High Speed and High Precision Motion Platform

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Abstract: As a general-purpose technology in the field of manufacturing and assembly, high-speed precision motion control technology is widely used in high-end manufacturing equipment such as chip packaging equipment and high-speed CNC machining centers. In order to further improve the speed and accuracy, a control method based on adaptive feed rate in the position domain is proposed. Where the curvature is large, the contour error is large, and the feed rate affects the performance of the contour accuracy, which in turn affects the quality of the contour control. In order to cut back the contour error when curvature changes greatly, feed rate is adjusted according to the contour error. The control method uses the adaptive feed rate for real-time interpolation. The variable feed rate is more conducive to the control accuracy in steady state and transient state. Adjust and adaptively adjust the feed rate. Through experiments, the performance indicators of the positioning platform (including positioning accuracy, repeat positioning accuracy, maximum sTable speed and maximum acceleration) were measured. The validation results show that the high speed and high precision positioning platform constructed can meet the high-speed and high-precision positioning requirements of mechanical packaging mechanisms proposed by IC packaging equipment and high-speed CNC machining centers.

1. Introduction

At present, in order to improve the production speed and quality of the product, and to pursue the high precision and high speed of the contour control of the motion platform, a multi-axis synchronous motion platform contour control technology and a composite technology such as translation and rotation are required. In the past, when the technology of tracking control by each axis was applied to a multi-axis system, the synchronization coordination and corresponding matching between the axes became more difficult. The traditional control design theory is not easy to improve by good command interpolation and learning control. In the face of more and more complex systems, new thinking is needed to look at the contour control problem of the motion platform.

The research on high-speed, high-acceleration and high-precision motion servo control systems in foreign countries is relatively early, especially in the developed countries such as Europe, America, Japan, etc. The production technology and application technology of linear motors and their drives are relatively mature, and as a kind of the new feed motion drive method has greatly promoted the development of high-speed machine tools and other precision equipment [1-3], and has profoundly promoted the development of domestic manufacturing. For the research of high-speed, high-precision positioning platform for electronic packaging equipment, [4] the two-axis linkage high-speed, high-precision positioning platform constructed by [4] is driven by a linear voice coil directly. At the same time, the platform mechanical structure adopts a new type of elastic relief mechanism, which places the driving components on the base, which reduces the weight of the moving parts and reduces the inertia. [5,6] Linear synchronous motor for driving X and Y axes. The strokes are designed to be 400~ and 340mm respectively. The whole workbench uses double-zero precision granite as the base. The positioning accuracy of the platform X-axis is 5.96um/100mm, and the repeat position accuracy is 2.88um; the Y-axis repeat positioning accuracy is 518um/100mm, and the repeat position accuracy is 2.46um [7]. [8,9] A new high-push-weight ratio direct-drive air flotation positioning platform was designed for the performance requirements

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of the bonding machine for the positioning platform, and the corresponding position servo control system was designed. Positioning platform servo system position loop adopts PID control. When the speed loop adopts PI control, the positioning accuracy of the platform can reach 4um, the maximum acceleration of the X-axis, the Y-axis is 8.78g and 8.05g respectively; when the speed loop adopts PDFF (pseudo-derivative) When controlling, the positioning accuracy of the platform can reach 3mm, and the maximum accelerations of the X-axis, the Y-axis are 7.87g and 7.38g, respectively. When the speed loop is controlled by the pole configuration, the positioning accuracy of the platform can reach 2mm, X-axis, Y-axis. The maximum acceleration is 8.00g and 7.34g.

The choice of current motion platform control methods depends on the requirements of the application. For example, precision, speed range, and calculation accuracy of the motion stage are also difficult to really improve the force, motion characteristics (repetition) and so on. Because the contour error model is not accurate, so control, this is one of the main shortcomings of the previous control strategy. In order to further improve the speed and accuracy, a control method based on adaptive feed rate in the position domain is proposed. Where the curvature is large, the contour error is large, and the feed rate affects the performance of the contour accuracy, which in turn affects the quality of the contour control. In order to cut off the contour error when the curvature changes greatly, the feed rate is adjusted according to the contour error. The control method uses the adaptive feed rate for real-time interpolation. The variable feed rate is more conducive to the control accuracy in steady state and transient state. Adjust and adaptively adjust the feed rate. Through experiments, the performance indicators of the positioning platform (including positioning accuracy, repeat positioning accuracy, maximum sTable speed and maximum acceleration) were measured. The results show that the high-speed precision position platform constructed could meet the high-speed, high-precision positioning requirements of mechanical packaging mechanisms proposed by IC packaging equipment and high-speed CNC machining centers.

2. High-speed precision motion platform overall control strategy

(1) Overall design of high-speed precision positioning platform

The functional requirement of the control system designed and constructed in this paper mainly include the following:

1) The system motion platform has a three-axis linkage function (the linkage axes are the X-axis, the Y-axis, and the Z-axis);

2) The number of control axes and hardware modules of the system can be expanded;

3) X-Y axis Table can realize high speed, high acceleration and high precision motion control;

4) The platform should have micron-level positioning accuracy and repeat positioning accuracy;

5) The platform control system should be open and have a friendly user interface;

6) The system has high-precision linear and circular interpolation functions, and can execute motion programs and PLC programs;

7) The system is resistant to external environmental influences.

The XY Table of high-speed, high-precision position platform is directly driven by permanent magnet synchronous linear. The maximum movement stroke of each motion axis is X-axis 750mm} Y-axis 1000mm respectively; under the no-load operation condition, the total mass of X-axis moving parts For 5Kg, the total Y-axis mover parts is 48Kg. The main performance indicators of linear motors are shown in Table 1.

(2) Mathematical model and contour error analysis of biaxial motion platform

The motion platform is composed of two vertical movements of the X and Y axes to produce a motion trajectory. If s(t) is used to represent the mathematical expression of the two-dimensional curve, $x_1(t), x_2(t)$ represents the position output function of the X and Y axes, respectively. Then

$$s(t) = f(x_1, x_2) \tag{1}$$

The rotary motor is cut along the axis and expanded into a straight line, and a linear motor is theoretically obtained. In PMLSM, the circumferential, axial and radial directions of the permanent magnet synchronous motor are called longitudinal, transverse and normal directions [10]. The working principle of PMLSM is similar to that of rotating electric machines. An air gap magnetic field is generated when symmetrical sinusoidal is applied to the three-phase winding of the PMLSM mover. The distribution is similar to rotating electrical machine when the longitudinal end effect due to the breaking of the two ends of the core is not considered, that is, it can be regarded as a sinusoidal distribution in the direction of the unfolded straight line. This principle is similar to the principle of a rotating electrical machine, but the difference between the two is the air magnetic field of the PMLSM does not rotate but moves in a linear direction, so the magnetic is called a wave magnetic field.

Table 1 Linear motor soil performance indicators

Specification	Symbol	Unit	X axis	Y axis
Phase	ϕ	ϕ	3	3
Continuous thrust	Fc	N	109	195
Instant thrust	Fp	N	357	585
Thrust constant	Kf	N/A	54.5	97.5
Continuous current	Ic	A(ms)	2	2
Instantaneous current	Ip	A(ms)	6	5
Phase-to-phase inductance	L	mH	4.4	9.6
Phase resistance (250C)	R	Ω	6.7	9.6
Electrical time constant	Ko	ms	1.0	0.4
Pole distance	2τ	mm	3.2	43

The trajectory accuracy is often restricted by both electrical and mechanical aspects. The trajectory error is inevitable in both tracking error and contour error. When designing PML SM to directly drive the XY platform contour controller, different contour error models are established according to the different requirements of contour machining. The following describes the linear trajectory error model, the circular trajectory error model and contour error model of any trajectory. The contour calculation model is simple and easy to calculate. It is the angle of the desired trajectory and X axis. At t time, the point on the desired trajectory is R, and the point on the actual trajectory is P, according to the contour. The definition of the error, the tracking error phoenix is the distance between the point P and the point R, and the contour error is from the point P to the desired processing trajectory. According to the geometric relationship in the figure, the tracking with X-axis, tracking error of Y-axis and the angle between the desired machining path and the X-axis can be calculated to calculate the contour error. The formula is:

$$E_c = E_y \cos\varphi - E_X \sin\theta \tag{2}$$

The circular contour error can be calculated from the current motion position and the circular radius of the circular path: calculated, which can be described by mathematical expressions as:

$$E_c = \sqrt{(P_x - X_0)^2 + (P_y - Y_0)^2} \tag{3}$$

Based on the previous research content, based on computer control and digital signal processing technology, Z-transformation is described in discrete time systems. The role of the Notch notch filter is to prevent resonance, With eliminate the mechanical resonance on the control accuracy, so as to the high-speed, high-precision positioning requirements of test platform. The Pm control parameters, speed feedforward parameters, acceleration feedforward parameters and control parameters of the Notch notch in the PMAC control algorithm are all adjusTable. The symbol definition and variable modification customization are shown in Table 2:

Table 2 PMAC control parameter definition

PID parameter			Notch notch coefficient	
Symbol	Variable address	Name	Symbol	Variable address
Kp	Ixx30	Proportional gain	N1	Ixx3 6
Kd	Ixx31	Integral gain	N2	Ixx3 7
Kvff	Ixx32	Speed feedback gain	D1	Ixx38
Ki	Ixx33	Integral gain	D2	Ixx39
IM	Ixx34	Integral mode selection		
Kaff	Ixx35	Acceleration feed forward gain		

Before testing, set all servo control parameters to zero and then only debug the proportional gain (Ixx3). In the step response test, set the step step to 1000cts (0.1 mm), the single-pass time is 500ms, first set the Ixx30 to a small value of 100, and use the grating scale feedback to collect the motion displacement of the platform to obtain the Y-axis linear motor step. The response curve is shown in Figure 1:

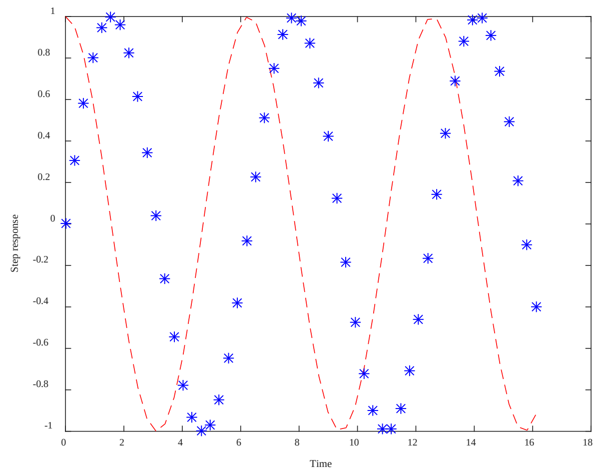

Figure 1 Y-axis step response curve

As shown from the step response curve shown in Figure 1 that when the proportional gain is small, the system response is slow, and the time required for the output signal to reach the command value is longer, and it is necessary to increase the proportional gain _ and then gradually increase the ratio. Gain coefficient Ixx30 value.

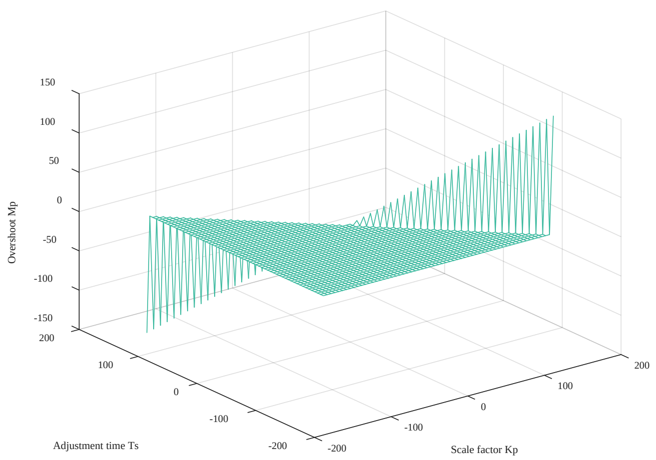

Figure. 2 Change law of system parameter Kp

As shown in Figure 2, the function of the P regulator is to immediately output an adjustment amount proportionally when the system has an adjustment deviation, which produces a rapid response to the adjustment deviation that occurs. However, the P regulator could not completely eliminate the deviation. There is an adjustment static difference in the adjustment process. The magnitude of the adjustment static difference is related to the transmission coefficient Kp. The larger the Kp is, the smaller the adjustment static difference is; however, the transmission coefficient cannot be increased indefinitely because If Kp exceeds a certain value, the regulation loop will become unsTable and start to oscillate; at the same time, Kp should not be too small, otherwise the system will respond slowly.

3. Conclusion

In order to cut off the motion platform contour where the curvature is large, the adjustment of the adaptive feed rate affects the contour accuracy. For complex curves, low feed rates are used for areas with high curvature and high feed rates for areas with small curvature. By adaptively adjusting the feed rate, the accuracy is high and the contour error can meet the high precision requirements. Using the debugging software provided by PMAC, repeated debugging experiments were carried out on the position controller PID control parameters and speed/acceleration feedforward parameters of the linear motor servo control system of the motion platform, so that the whole servo control system obtained good steady state performance and dynamic performance, and the influence of control parameters of servo control system is summarized.

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