EFFECTS OF AMB POWER AMPLIFIER STRUCTURE UPON THE SYSTEM PERFORMANCE

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ABSTRACT

Aiming at the effects of the coil inductance upon the anti-jamming abilities of the high-speed Active Magnetic Bearing (AMB) system, in this paper, the effects of AMB Power amplifier structure upon the system performances are analyzed. Based on this, the AMB Power amplifier structure are improved, and then the system rigidity and the rotative precision of the spindle increase. At the end of this paper, a high-speed AMB system is simulated dynamically. Effects of two difference AMB Power amplifier structures on the system dynamic rigidity are analyed and compared. The resunlts from simulation are in agreement with theory conclusions.

1. INTRODUCTION

AMB is a new type of bearing. Suspending the spindle by magnetic force the bearings has many advantages such as no wear, no-lubrication, long-life. Its dynamic properties can be adjusted, so that this kind of bearing is used widely. But AMB is inherently unstable. A position feedback control is needed to ensure system stability. How to apply modern controlling theories to increase system stabilization and robust property has always been a hotspot in this field [1,2]. But the effects of the power amplifier structure on AMB system performances are ignored. Considering the effects of the AMB induct load, [3] suggests to introduce current feedback to widen frequency range of power amplifier system. Rigidity of the system could then be assured. In this case, a higher rotating speed and precision could be reached. But the auther [3] didn't considered the effects produced by current feedback upon the system control signal. In the chapter, the author indicates that if the power amplifier structure is not modified when the current feedback is adopted, the new control signal can not be processed correctly by the old power amplifier structure, so that the anti-jamming abilities would not be increase.

2. EFFECTS OF THE POWER AMPLIFIER STRUCTURE UPON SYSTEM PERFORMANCE

2.1 Effects of Current Feedback on the Control Signal

An AMB close-loop controll system is shown in Fig.1. In order to decrease the non-linearity effects of magnetic force, a differential working mode is used,

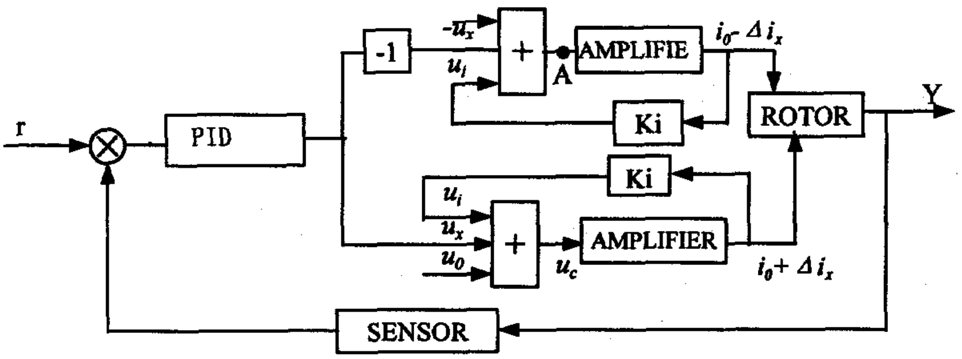


FIGURE 1: AMB closed differential controlling system

namely, coil currents in any pair of coils in a AMB would be $I_0 + \Delta i_x$ and $I_0 - \Delta i_x$. As shown in Fig 3(c), the current in upper coil is changed in the reverse direction relative to lower coil current. While upper coil current reaches maximun, the lower coil current happens to be equal to zero, and the differential magnetic force will be the largest. In the system, constant voltage u_0 produces bias current I_0 and this current is used to produce the static working point. The controlling voltage u_x produces the controlling current Δi_x, so that the controlling force is produced.

An amplifier of the AMB system is shown in Fig.2, the input of power amplifier is the voltage and the output is coil current. Accordingly, it is a typical one-order system and the critical frequency is $w_c \approx R/L$. According to the working principle of AMB, and with the rotate speed of the rotor increasing, the frequency and amplitude of eccentric force will increase with the rotate speed. In order to ensure the system stability, the frequency and amplitude of the bearing controlling current Δi_x are required to incease gradually. Owing to the attenuation characteristics of the high frequency of one-order power amplifier, and when the frequency of controll voltage u_x is larger than the critical w_c, the amplitude of the controlling current Δi_x will decrease. For the AMB system, this means an increase in the rotating speed, the dynamic rigidity would reduce gradually. This goes against an increase in the rotating speed. In order to improve the effects of the AMB inducting load, as shown in Fig.1, the current feedback (proportion k_i) is introduced into the AMB control system. As a result of the introduction of the current feedback, the voltage input of the AMB power amplifier system is changed into: $u_c = u_0 + u_x + u_i$, the critical frequency of the power amplifier is increased from the primary $w_{c1} \approx R/L$ to $w_{c2} \approx R(1+k_i)/L$. In order to ensure the differential work of the AMB system, $|\Delta i_x|$ should be less than or equal to I_0, Accordingly, when the rotate speed of the rotor is less than w_{c1}, and according to the amplitude-frequency characteristics of the power amplifier, the equation $|u_x + u_i| \le u_0$ should be allowed with means that the controlling voltage u_c is always positive. When the rotate speed is lower than w_{c2} or higher than w_{c1}, and in order to make the AMB have the same anti-jamming abilities as that frequency lower than w_{c1}, the

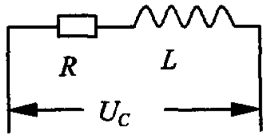
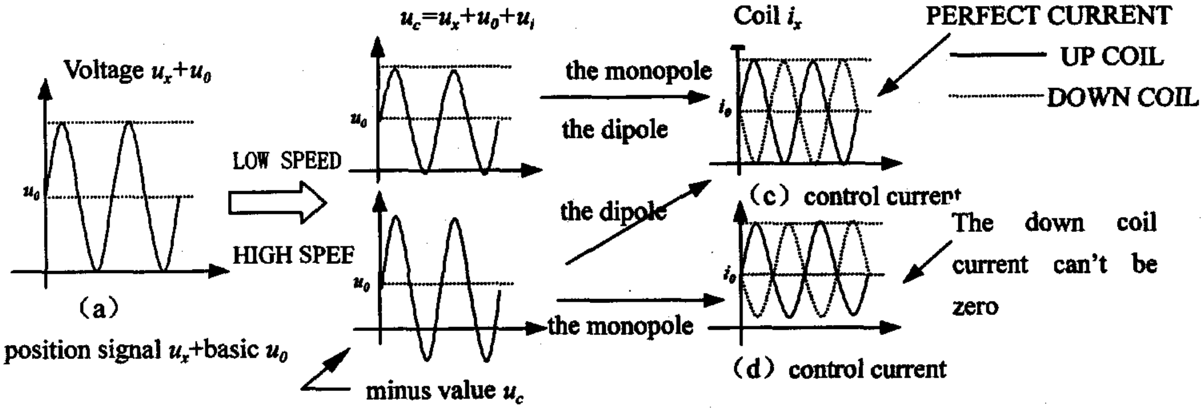


FIGURE 2: RL amplifier



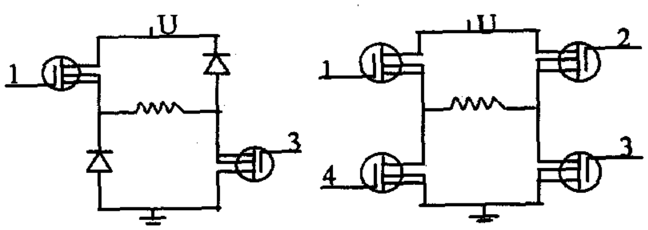
(b)the value at point A in fig 1

FIGURE 3: Voltage and current of switching amplifier,

amplitude of the controlling voltage $|u_x + u_i|$ may be larger than u_0, that is to say, negative controll voltages u_c could appeare (as shown in Fig 3(b)).

2.2 The Power Amplifier Structure of AMB

In order to reduce power losss, the PWM switching



(a) The monopole structure (b) The dipole structure

FIGURE 4: PWM switching amplifier

amplifier[4, 5] is used in the AMB system . There are mainly two structures: monopole and dipole (as showned in Fig.4. The basic principle of the power amplifier is: the ratio between conducted state and closed state is defined by the amplitude of controlling voltage u_x; the polarity of the voltage input u_x decides the working mode of the power amplifier. If the controlling voltage input u_x is positive, switch 1 and 3 would switch on; if input controlling voltage u_x is negative, then switch 2 and 4 would switch on. Fig.4 (a) is a monopole power amplifier structure, only monopole current can be produced in the bearing coil. As mentioned above, if current feedback was not used, Eq $u_c \geq 0$ comes into existence; and the input voltages is always positive; the system can use the monopole structure (as expressed in Fig 4a). After introducing current feedback, the negative input voltages u_x may appear. In order to ensure the high frequency dynamic rigidity, the dipole structure should be used in the AMB power amplifier structure (as expressed in Fig 4b). If the monopole structure is still used, the bearing coil controlling voltages can not be magnified normally so that the system dynamic rigidity will be reduced.

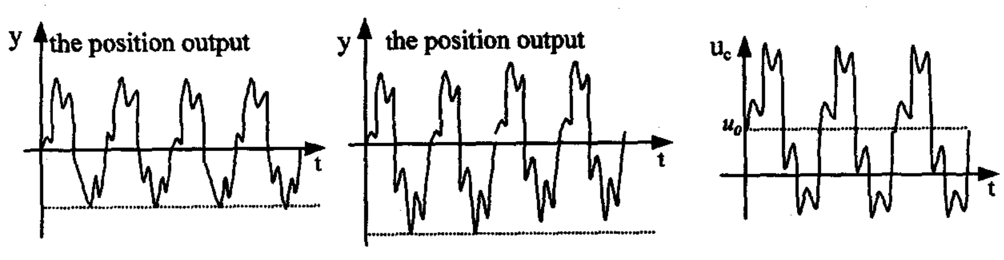
3.THE SIMULATION ANALYSIS

Table 1 shows the parameter of a certain high-speed AMB grinding machine. When the current feedback is not used, the critical frequency of the power amplifier is about 170Hz. When the current feedback is used ($k_i = 4.8$), the critical frequency of the power amplifier increases to about 1000Hz.

TABLE 1: The parameters of AMB

Rotor mass	m=2kg
Nominal gap	δ_0=0.2mm
Number of coil turns	N=100
Inductance of coil	L_0=2.4mH
Resistance of coil	R=2.6 Ω
Power supply voltage	U=30V
Current	I_0=3A

Taking the experimentation platform as a simulation model, the PID controlling is used in the position loop of AMB system and the proportion feedback is used in the current feedback control. During simulating process, at first, adjusting the parameter of the controller making the system is steady, then .a disturbance is put on the rotor. When the disturbing frequency is lower than



(A) Dipole structure output (B) Monopole structure output (C) Control current

FIGURE 5: Imbalance response of the system at 600Hz

170Hz, the simulating results can indicate that power amplifier uses either the monopole or the dipole structure, the amplitude of vibration is always the same. That is to say, the two kinds of power amplifier structure have the same system dynamic rigidity in low frequenc. When the system disturbance frequency varies between 200Hz and 1000Hz, the simulation results indicated that the anti-jamming abilities of the both power amplifiers structure systems is quite different. Fig.5A and 5B show the position response to the AMB system with two power structures when the disturbance frequency is 600Hz. As shown in the Fig5A, the system output amplitude in the positive or negative directions is the same when the dipole structureis used. In the Fig5B, the system output amplitude in the negative direction is larger than the positive one because of using the monopole structure. At the same time, the power amplifier input voltage u_c is observed, the wave is shown in Fig.5C, and the negative input voltage u_c appears. Then the monopole power amplifier can not amplify the negative controlling voltage normally whereby resulting in a reduction in the system rigidity. The results from simulation indicate that in order to improve the system dynamic rigidity effectively, the current feedback is used in the AMB, because of the change of the controlling voltage, the dipole power amplifier should be used.

4. CONCLUSION

Introducing the current feedback in AMB system can help to compensate the attenuation which is produced in high frequency current. After introducing the current feedback, the dipole power amplifier structure must be used in the switching amplifier so as to improve the high frequency dynamic rigidity of the system and the rotate precision of the rotor.

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