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Research Article

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Analysis the data of chaotic operation on ultrasonic motor system

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ABSTRACT

In this paper, we designed a closed loop control system of ultrasonic motor, found the phenomenon about the random irregular movement of motor-speed and analyzed the data of speed, simulated the bifurcation diagram of the speed about motor control system, calculated the speed of sampling value on the maximum Lyapunov index, the calculation result was greater than zero, it was further proved that the system was chaotic system.

Key words: Ultrasonic Motor, Rotating speed, Chaos

INTRODUCTION

For the driving system of ultrasonic motor, the research on the chaotic characteristics of the system is a little later, and most of research are based on computer simulation, the motor test data of its chaotic characteristics are few. At present, in the field of the driving system of ultrasonic motor about the chaos research is mainly around the motor , reports on chaos control of ultrasonic motors are rarely. The control strategy of ultrasonic motor has a good control effect, but the research founds that, when the control parameters or external environmental are changed, the motor sometimes shows its Characteristic about seemingly random irregular movement, mainly shows the oscillation of indirect speed and torque, the motor's energy is lost, and affects the performance of the motor running, shortens the life of the motor. It is a little difficulty for the motor with Irregular running, which can be applied in high precision devices and more accuracy of position control system.

THE CHAOTIC PHENOMENA OF ULTRASONIC MOTOR

In order to enhance the ultrasonic motor application in the industrial field, we not only use the driving control system because of its good stability, high precision and good speed tracking function, but also utilize the power output and the optimization efficiency of the system. Experiments show that, the speed of the motor is sometimes irregular vibration, the output efficiency is affected. The traditional control method is difficult to solve this kind of irregular vibration. Previously, people always think the irregular movement of the motor is due to the precision of the system or external interference, people's thought of solving this problem are fettered. Due to the serious nonlinear body of ultrasonic motor and its driving control system, we comparison the running characteristics of motor with its chaotic behavior, that the result is very similar. The theoretical and practical research on the ultrasonic motor driving system about the theory of chaos from the reason and process of the motor irregular movement is very important, which is given us an important inspiration to solve the irregular running of the ultrasonic motor system.

BUILT A TEST PLATFORM OF ULTRASONIC MOTOR

In order to test the speed of ultrasonic motor about its chaotic behavior with the irregular running, we build a test platform of ultrasonic motor and its driving control system, the structure diagram is as shown in figure 1. The system about the speed of closed-loop control system has two phase driving voltage amplitude, the controlling voltage value will been kept consistent at the same time and eliminated the phenomena about the change of voltage amplitude with frequency in the open-loop system, we relieve the coupling relationship about the frequency and input voltage value of the motor, improve the speed control performance. The outer controlled-loop is designed to regulate the amplitude of voltage through voltage frequency controller, to change the frequency of the piezoelectric ceramic motor, to realize the speed steady state control, to eliminate the error of steady state in the system. We use the type of" Shinsei" USM60 traveling wave ultrasonic motor as the experimental motor. In the system , we use the DSP 56F801 chip controller as the mainly control chip, connect the upper monitor with PC , so as to observe the acquisition of motor speed, the motor driving circuit voltage is DC12V, rotary encoder("E")is connected with the motor coaxial rigid to acquaint real-time feedback signal of the motor speed, the signal is transmitted to the lower computer controller to control the motor speed. At the same time, the signal is transmitted to the PC through the serial communication, and the real-time processing of the signal is handled with the upper PC software system to analyze the chaos data.

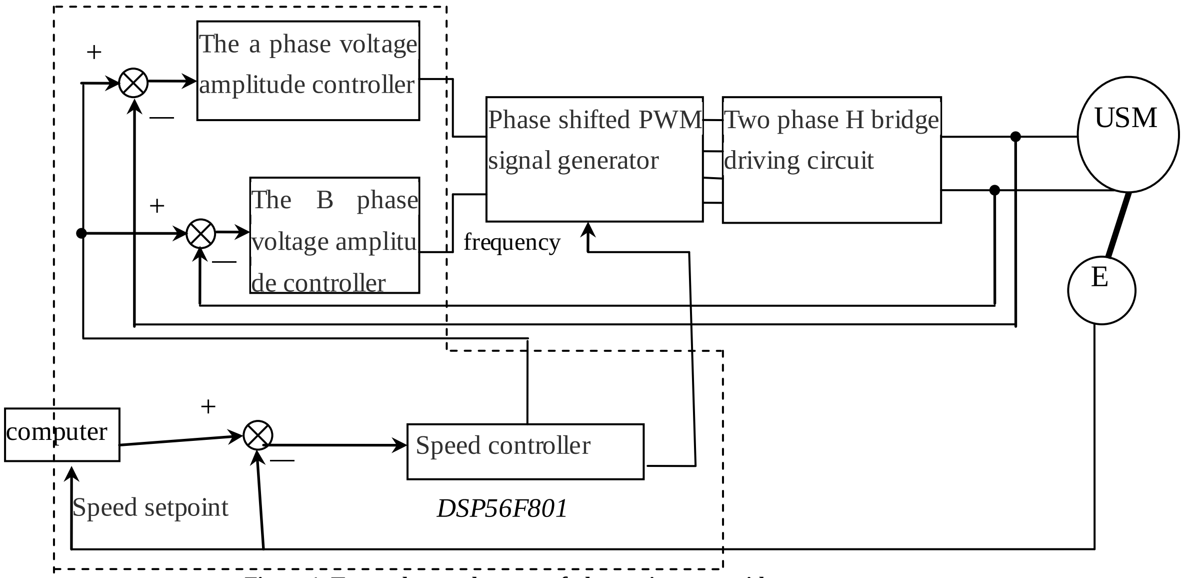

Figure 1. Test and control system of ultrasonic motor with computer

ANALYSE THE CHAOTIC CHARACTER OF TRAVELLING WAVE ULTRASONIC MOTOR SPEED CONTROL SYSTEM

Ultrasonic motor and its driving circuit has strong nonlinear characteristics, the main coupling parameters of motor will produce many unstable factors within motor running process. For example, a piezoelectric ceramic on the temperature sensitivity, will be changed the resonance frequency, thereby affected the open-loop system motor speed; The energy of ultrasonic motor involves electric energy will be conversed into mechanical energy through the stator, then the mechanical energy will be conversed into the rotor through friction, the transferring energy will also affect the motor speed; The motor's nonlinear problems and external uncertain factors from the motor driving circuit components, will also affect its speed. Chaos is a typical nonlinear operation status. The research of chaos operation of motor system contributes to maintain the stable operation of motor system and provides necessary foundation for the control of chaotic motion by recognizing the chaos nonlinear phenomena in a new perspective.

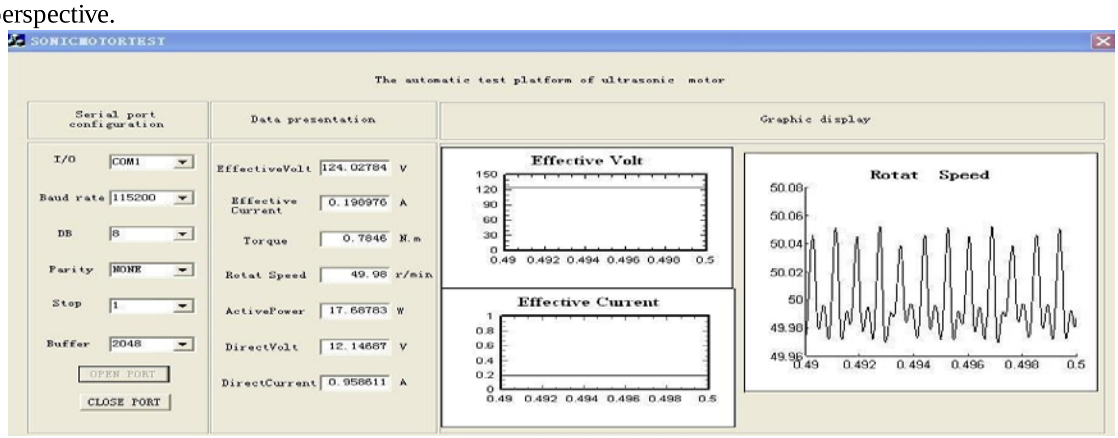

Figure 2. The curve about actual test data of ultrasonic motor speed

At present, the general method is used to do with the tested data, such as using mutual information method and Cao method to calculate the delay time and the minimum embedding dimension, the dynamic behavior of the recovery system, also calculate the maximum Lyapunov index to judge whether the ultrasonic motor system shows chaotic characteristics or not.

In order to analyze the ultrasonic motor chaos phenomena by the method of time sequence phase-space reconstruction, The first step is through the upper PC software system, the measured signal is imported into Matlab software, respectively, by using mutual information method and Cao method to calculate the speed of the calculation of sampling signal time delay τ and embedding dimension M.

The second step: the calculation of the maximum Lyapunov exponent

On 1983, Gerry bases that as long as the maximum Lyapunov exponent is greater than zero, it certainly is in chaos. In the process of determining whether a system chaos in computing the largest Lyapunov exponent need. The simulation of the small data method to calculate the largest Lyapunov exponent.

Calculation method of small amount of data:

1 the time series of FFT transform, the calculation of average cycle P;
2 computing the delayed time and the embedding dimension m;
3 according to the time delay and embedding dimension of phase space reconstruction;

4 The ne Y_j arest neighbor for each point $\hat{Yj}$ in the phase space and limit the temporary separation, i.e.

$$d_j(0) = \min \| Y_j - Y_{\hat{j}} \|, |j-\hat{j}|>P \tag{1}$$

5 for each point Y_j in phase space, the calculation of the adjacent point i to after a discrete time step distance

$$d_j(i) = | Y_{j+i} - Y_{\hat{j}+i} | \quad i=1,2,\ldots\min(M-j, M-\hat{j}) \tag{2}$$

6 for each j, and find $\ln d_j(i)$ of all the average, i.e.

$$y(i) = \frac{1}{q\Delta t}\sum_{j=1}^{q}\ln d_j(i) \tag{3}$$

Where q is the number $d_j(i)$ of non zero, Δt is the sample period. Using the method of least squares to make regression straight line, the slope of the straight line is the largest Lyapunov index, if the maximum Lyapunov index is positive, it shows that chaos exists.

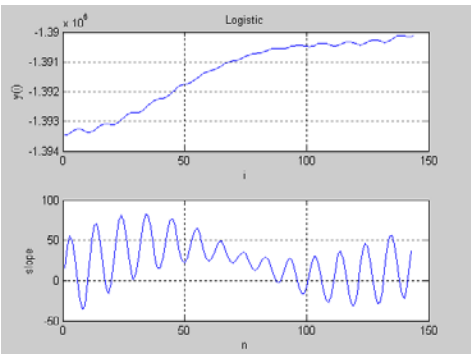

Figure 3. The largest Lyapunov exponent speed

Through the verification of the above methods, the largest Lyapunov exponent diagram can be drawn from this graph, you can clearly see, calculating the largest Lyapunov exponent is positive, it can determine the actual motor speed sampling signal sequences showed strong characteristics of chaos, chaotic operation characteristics of ultrasonic motor and drive control system construction.

The data processing by using mutual information method and Cao method to calculate the delay time and the minimum embedding dimension m, calculated for different driving voltage and with a minimum amount of data (KIV) value of the largest Lyapunov exponent speed. By adjusting the different voltage value method, drawing speed maximum relative to the bifurcation diagram in figure (KIV) to further validate the interval chaotic operation of the motor, as the implementation of chaos control, laid the foundation for the study of good.

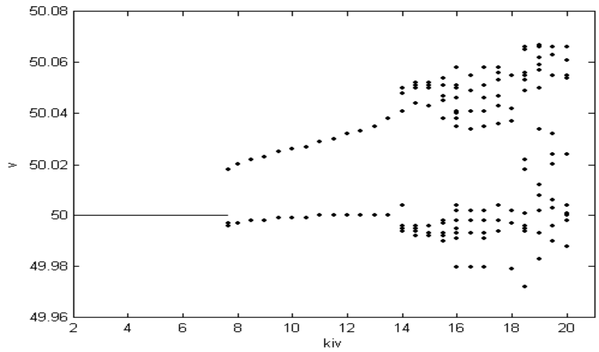

Figure 4. Maximum speed relative to the bifurcation diagram in figure (KIV)

CONCLUSION

Research shows that, the nonlinear motor driven nonlinear characteristics of ultrasonic motor and control system, built a system, carry out the collection of motor speed signal chaotic data processing, respectively, by using mutual information method, Cao method for delay time, the minimum embedding dimension and Lyapunov index was calculated, verify the traveling wave ultrasonic motor speed closed-loop control system under certain operating conditions, can exhibit chaotic behavior significantly, the Lyapunov spectrum and the phase plane graph as the basis, the cycle region and chaotic range of ultrasonic motor, studies show that when the parameters change, the ultrasonic motor is easy to exhibit chaotic characteristics.

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