THE SUMMARY OF Ph.D. DISSERTATION

School of Integrated Design Engineering		TAKEMURA, Kenjiro

Title

Practical Design of Multi-DOF Ultrasonic Motor and its Drive Control using Non-linear Inverse Model

Abstract

Actuator is one of the most important components for mechanical systems. As a number of degree-of-freedom (DOF) of motion for mechanical system increases, development of multi-DOF actuators becomes even more important topics. For that reason, the author designs a new type of multi-DOF ultrasonic motor and its controller using a non-linear inverse model.

Chapter 1 summarizes a background of the paper and previous studies.

Chapter 2 describes driving principle, geometry design and production of a multi-DOF ultrasonic motor. The ultrasonic motor consists of a columnar stator and a spherical rotor. The rotor rotates around three perpendicular axes using three frequency-corresponding natural vibration modes of the stator whose directions are perpendicular to each other. The stator geometry and its vibration modes shapes are designed using a finite element method. The designed stator is produced and then the multi-DOF rotation of the real rotor is achieved. The driving characteristics of the multi-DOF ultrasonic motor are measured.

Chapter 3 describes numerical analyses of the multi-DOF ultrasonic motor. First, a forward model for the input parameters/driving state relation of the multi-DOF ultrasonic motor is proposed. In the forward model, the rotor/stator contact area and a cycle of vibration are divided into dispersed points and time, respectively. Then, rotational axis, rotational speed, output torque, efficiency and rotor/stator contact condition under arbitrary combination of the three vibrations, which are difficult to be measured experimentally, are numerically analyzed considering the frictional force between the rotor/stator. Second, an inverse model for the driving state/input parameters relation of the multi-DOF ultrasonic motor is constructed. Although the multi-DOF ultrasonic motor has non-linear and redundant characteristics, its inverse model is constructed using the knowledge of ultrasonic motors and neural network technique. Parameters of the three alternating inputs for realizing the desired driving state of the rotor are determined using the inverse model.

Chapter 4 proposes a novel control method for the multi-DOF ultrasonic motor. There are two candidates for the control method. One is to control the multi-DOF rotation as a combination of individual single-DOF rotations. The other is to control all the DOFs of rotation simultaneously using the inverse model. It is clarified from the numerical comparison between two control methods that the latter is superior to the former one as to understand the spatial position of the rotor. As a result of the multi-DOF motion control tests, a tip of output axis of the rotor successfully follows the desired trajectory using the inverse model based controller.

Finally in chapter 5, conclusions of this study are described.