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Title(English)	Motion Control and Measurement of a Thin and Compact Linear Switched Reluctance Motor with a Film Mover
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	メカノマイクロ工学　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis is entitled as “Motion Control and Measurement of a Thin and Compact Linear Switched Reluctance Motor with a Film Mover”. It consists of five chapters.

In Chapter 1, firstly, the background of this study is described including the characteristics, applications and state of research of switched reluctance motors (SRMs). The newly developed linear switched reluctance motor (LSRM) and its application example are introduced. It does not include permanent magnets (PMs) and is therefore free from the attractive force of the magnets. Hence, the components can be easily assembled, disassembled, and recycled. The LSRM without PMs has a simple structure, which is a suitable characteristic for a thin and compact motor. Made using readily available materials, the mover can be considered disposable. However, similar to most LSRMs, the motor has a strong nonlinear driving characteristic that presents a challenge with respect to precision positioning and motion. Furthermore, for the ease of replacing and disposing, the mover without any sensor parts on it is desirable. Therefore, the research purpose is (1) to realize precise positioning by compensating the nonlinear characteristic; (2) to realize precise motion by overcoming the problems resulting from the fluctuating and limited thrust force characteristic; and (3) to realize motion measurement without the need to add sensor parts on the mover.

In Chapter 2, the research subject is “Design of precision positioning control system”. The mechanical characteristic of the developed LSRM is investigated and the dynamic model simulating the nonlinear driving characteristic is derived. It is clarified that the generated thrust force depends on the mover position and excitation current, and the coefficient of friction depends on the normal force. The positioning results and the problem associated with the conventional PID control system are described. Next, the linearizer unit is constructed using the derived dynamic model to compensate the nonlinear characteristic of the LSRM. The positioning control system was designed using the combination of the conventional PID controller and the proposed linearizer unit, and its effectiveness is validated experimentally. The experimental positioning results show that the control system has short settling time of less than 0.5 s and high accuracy with positioning error smaller than 0.25 μm, independent of the step height and change in direction. The positioning error of the positioning control system with the proposed linearizer unit is reduced by 50% compared with the conventional PID controller.

In Chapter 3, the research subject is “Design of precision motion control system”. To meet the objectives of the motion system, i.e., simplicity of use and mover exchangeability, the motion performance should remain the same even when the mover is exchanged. First, the control system for precise motion was designed based on the positioning control system with the proposed linearizer unit and additional

control elements. The additional control elements comprise a FF element and a disturbance observer. Then, because the robustness of the motion control system is critical, the effects of changing the length and mass of the movers on the motion accuracy and response were also experimentally investigated. The experimental results show that the motion performance remains the same with motion errors within 5 μm. Next, the limitations of the motion performance are clarified for mechanisms with a small effective thrust force such as those used in the developed LSRM. Even when the length and mass of the mover change, the experimental results indicate that the performance is maintained within the limitations determined based on the motor characteristics. The condition is considered to include the relationships among the mass of the mover, frequency and amplitudes of the sinusoidal input. Lastly, the temperature of the coils by the motion control system is measured to know the extent of the temperature rise at the time of driving.

In Chapter 4, the research subject is “Motion measurement without additional element on the mover”. As mentioned previously in Chapter 1, the novel feature of the mover is that it can be disposable. However, the experiments conducted in Chapters 2 and 3 rely on the sensor scale attached on the upper surface of the mover that is compatible with the linear encoder to detect its motion. An alternative method is necessary to acquire the motion without the sensor scale to eventually increase the disposability of the mover. A motion measurement system without any sensor parts on the mover is proposed. The configuration of the measurement system makes use of the LSRM that can easily integrate two non-contact eddy current sensors into the motor. The sensors are free from the attractive force to the mover cores. The uniform arrangement of the mover cores at regular intervals can act as a ruler for motion measurement. The proposed method is robust to reproducible amplitude variation of the output signal due to the deformation of the mover. The experimental results involving the validation of the measurement accuracy are described. Finally, motion performance of the control system using the proposed measurement system as a feedback sensor is examined experimentally.

In Chapter 5, summary and future works are described.