論 文 の 内 容 の 要 旨

論文題目　　周波数特徴に基づいたモータドライブシステムにおける
振動抑制制御に関する研究
(Study on Vibration Suppression Control in Motor Drive System
Based on Frequency Domain Characteristics)

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The performances of home and industrial appliances are constantly improved by modifying mechanical structures and control algorithms. In the various performance indexes, noise and vibration issues are known as one of the most important and difficult problems to be solved. As the improvements of other performances, the requirement for noise and vibration problems is increasing. Generally speaking, significant noise and vibration problems are caused in some specific frequencies because of the frequency characteristics of the mechanical structures and the excitation forces. Therefore, control algorithm with the explicit consideration of the frequency characteristics is a key technology to realize noiseless mechatronics system. In this dissertation, high performance vibration control technologies based on frequency characteristics are studied intensively.

The main work of this dissertation are conducted on two research regions. One is theoretical developments and practical applications of the sensitivity shaping algorithm based on Generalized KYP lemma and the other one is novel radial force modeling and control methods for IPMSMs. The main contributions of this dissertation are summarized as follows.

1. Radial forces in IPMSMs are known as the factor which causes unwanted noise and vibrations. In the previous literatures, radial forces are suppressed by changing mechanical structures. In this research, it is shown that the second order radial force fluctuation is caused by the fundamental flux of permanent magnet and dq-axis currents. The second order radial force modeling is conducted by considering flux distribution in IPMSMs. Based on the model, the fluctuation of the second order radial

force is suppressed by adding optimal negative d-axis fundamental current. The effectiveness of the suppression control algorithms is verified in simulations and experiments.

2. Sixth order radial force is easily transmitted and causes serious noise and vibrations. This is explained by the phase relationship of sixth order radial force on the U, V and W phase teeth. The origin of sixth order radial force fluctuation is the fluctuation of harmonic flux. Therefore, it is expected that the fluctuation can be suppressed by injecting harmonic currents. However, there is no literature which shows the transfer characteristics from harmonic current to sixth order radial force. In this dissertation, a novel approximate model of sixth order radial force is proposed by considering flux linkages on U, V and W phase teeth. The model enables to calculate the optimal harmonic current references by which sixth order radial force is suppressed largely.

3. Open-loop shaping approach is widely used to suppress the vibrations which are caused by harmonic disturbances. Recently, the open-loop shaping approach based on Generalized KYP lemma(GKYP lemma) is developed and it has a great potential to be applied in many mechatronics system. In this dissertation, practical development of the controller synthesis based on GKYP lemma is conducted by focusing on the parameter-dependency of transfer characteristics. A novel open-loop shaping approach for parametric controller design is shown relying on polynomial spline parameterizations. The proposed approach exploits the GKYP lemma to derive parameter-dependent linear matrix inequalities (LMIs) for parametric controller synthesis. GKYP lemma enables to consider multiple finite frequency domain specifications intuitively in order to design practical controllers. By assuming piecewise polynomial parameterizations for the parameter-dependent optimization variables, and subsequently applying B-spline based relaxations, tractable conditions are derived that guarantee feasibility of the parameter-dependent LMIs. the applications of robust controller synthesis problem with uncertain parameters and gain-scheduled controller synthesis are shown. The effectiveness is demonstrated by numerical examples.

4. In the mechatronics system, such as hard disk head positioning system, there are many resonant modes which cause unwanted vibrations, disturb system stability and restrict the feedback control performance. Generally, notch filters are used to suppress resonant modes at the expense of phase delay. This phase delay also restricts bandwidth. In this dissertation, a simultaneous design of a feedback controller and phase and gain stabilization compensator using Generalized KYP lemma. Generalized KYP lemma enables to optimize feedback control performance while considering mechanical resonant modes. Firstly, the structures of feedback controllers and

stabilization compensators are defined. Various control performances are formulated by frequency domain inequalities. By using Generalized KYP lemma, the feedback controller is optimized in consideration of various control performances. The effectiveness of the proposed design method is verified in the application examples to HDD benchmark problem.

This dissertation constructed the model-based control framework of radial force vibration in IPMSMs. Although these models were derived with some approximations, they are enough to be used in practical control algorithms. The simple and intuitive model also enables us to understand what vibration phenomenon happens in IPMSM motor drive systems. Theoretical improvements and practical applications of the control synthesis based on Generalized KYP lemma were also studied fully in this dissertation. Especially, the large parts of parametric GKYP synthesis problems are solved. The usefulness and industrial impacts are also shown firmly through the application of HDD head positioning system. Therefore, author believe that this dissertation will be a good guide for the academic and industrial engineers who would like to construct noiseless mechatronics system.