Title	不確かさを考慮した制御系のモデリングとロバスト性解析に関する研究-磁気浮上系における解析-
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Modeling and Robustness Analysis of Control Systems Considering Uncertainties
-Analysis of Magnetic Suspension Systems -

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This thesis considers the robustness analysis of magnetic suspension system against the structured uncertainty that enters in the feedback form. We propose the model of the magnetic suspension system with the structured uncertainty. We analyze the robustness of the proposed model and the unstructured uncertain model, and discuss the conservative of the result analyzing.

Robust control has been great advances in the theory for the design of robustly uncertainty-tolerant feedback control systems. The problem in robust feedback control system design is to synthesize a control law which maintains system performance and error signals to within the prespecified tolerances despite the effects of uncertainty of the system. This control method is applied to some physical system, such as Magnetic suspension system, air plane, and so on.

For the magnetic suspension system, the characteristic of the magnetic force is so complex that the analysis of this force is very difficult and no mathematical models can express the exact behavior of it. It is important from the above discussion that the control designer takes account of the uncertainty.

Previous researches for the magnetic suspension system have not represented the uncertainty between the physical system and the model. Recently the researches using robust control have represented the uncertainty with respect to this system. However the uncertain model is representation using the unstructured uncertainty model. Therefore the representation of the uncertainty is conservative. In the robust control problem, two types of the uncertainty are defined;*unstructured and structured uncertainty.* The unstructured uncertainty usually is represented frequency dependent element. For instance, there exists actuator saturations, unmodeld dynamics in the high frequency range, plant

disturbances in the frequency range. The structured uncertainty is represented parametric uncertainty in the plant dynamics. Previously many researches have dealt with the unstructured uncertainty. Since the analysis of robustness is simplified. However the result is conservative. It is clear from the above discussion that the analysis using structured uncertainty is better than that using the unstructured uncertainty.

Before it has been difficult to analysis the structured uncertainty. However recently researcher developed algorithms for the robustness analysis. Thus, the analysis using the structured uncertainty is to be easy by the CAD.

For these problem, we consider the following purposes of this thesis

- we considers the robustness analysis of magnetic suspension system against the structure uncertainty that enters in the feedback form。
- We think about the conservative of the result of the robustness analysis with respect to the unstructured uncertainty.

To solve these problem, we will consider as follow.

- We propose the uncertain model of magnetic suspension system using the structured uncertainty.
- We analyze the robustness of proposed model on the magnetic suspension system.

We exploit the μ synthesis on designing the magnetic suspension system. This analysis is carried out by mixed structured singular value. using μ- Analysis and Synthesis Toolbox and MATLAB.

Firstly, the issue of modeling the magnetic suspension system is discussed. It is important to discuss the modeling for building the uncertainty model. A derive a nominal mathematical model is derived. Generally, a mathematical model is required, however, there is no mathematical model can express the real physical system;that is, there exist inevitably the uncertainty in the mathematical model. By the uncertainty, we cannot predict exactly what the output of the real physical system will be even if we know the input, so we are uncertain about the system. Uncertainty arises from two sources: unknown or unpredictable inputs(disturbance,noise,etc.)and unpredictable dynamics. Real physical system is nominal mathematical model and descriptions of the remaining uncertainty which can be classified in the following classes: Parametric uncertainty, Unmodeled dynamics. Uncertainty in any form is no doubt the major issue in most control system design. For the magnetic suspension system, we will consider where uncertainties arise. They arise at the linearization of the electromagnetic force, the mass of the iron ball, and the part of electromagnetic. The perturbation of linearization of the electromagnetic force and the mass of the iron ball is parametric uncertainty. The part of electromagnetic arise Unmodeled dynamics. We drove derive the uncertain model for the magnetic suspension system which take account of the uncertainty. This model is represented as the structured uncertainty.

Secondary, given the derived uncertain model for the magnetic suspension system, the structured singular value (μ) can be used to analyze the robustness of the system with respect to the structured uncertainty that enters in the feedback form. We discuss the robust stability and the robust performance using the mixed μ. By μ synthesis we design controller K_{mu} to magnetic suspension system with the unstructured uncertainty, and make utility of the μ Analysis and Synthesis Toolbox for the robustness design and analysis. We can know the effect of the uncertain models of the magnetic suspension system, and discuss the conservative of the system with respect to the unstructured uncertainty. The uncertainty of this analysis consider the moving steady gap between the electromagnet and the iron ball. Moving the gap is correspond to varying parameter of the linearlization of the electromagnetic force and varying the nominal model. We consider the robustness analyses of the magnetic suspension system by moving the steady gap. We discuss the robust stability when the perturbation arise by moving the steady gap, further the conservative of the analysis result using the unstructured uncertainty.

Using μ, the robust performance characteristics can be evaluated. Under perturbation, the effect that these disturbance have on error signals can greatly increase. In order to contend this analysis, we design another pid control controller K_{pid}, the other H_∞mixed-sensitivity K_{mix}. The analysis result shows that K_{mu} is good performance.

Thirdly several experiments are carried out in order to evaluate this robustness analysis. We evaluate the stability of the closed-loop system against the uncertainty. It is correspond to the robust stability. In these experiments, the uncertainty of these experiments is moving steady gap between the electromagnet and the iron ball. Moving the gap is correspond to varying parameter of the linearlization of electromagnetic force and varying the nominal model. between the electormagnet and the iron ball. The experimental result is agreement with the theoretical analysis. From this analysis we investigated that robust stability analysis is valid. We will investigate the robust performance. We give psude-disturbances by adding a voltage signal to a control input signal since it is difficult to supply disturbance force directly to an iron ball is difficult. The experimental result is agreement with the theoretical analysis. From this analysis, we investigate that robust performance analysis is valid.

Finally, We discuss the uncertainty of the magnetic suspension system, and propose the uncertainty model with the structured uncertainty for this system. we investigated whether the unstructured uncertain model is more conservative than the structured uncertain model from this analysis.

we conclude that robustness analysis again the structured uncertainty is less conservative than the unstructured model.