学 位 論 文 の 要 旨

Study on minimum-phase controllers for minimum-phase plants

（最小位相系に対する最小位相な補償器に関する研究）

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In this thesis, a study on the parameterization of all minimum-phase stabilizing controllers for minimum-phase plants is considered. The parameterization problem is to find all stabilizing controllers for a plant, so as to make the system stable, and to obtain plants those can be stabilized. This method can effectively solve all the parameterization of the minimum-phase stabilizing controllers for minimum-phase system, so it has been applied in many practical problems.

Compared with the non-minimum phase system, the minimum-phase system has fast response, small energy delay, stable inverse system and other advantages. Comparing with the nonminimum-phase system constructed by configuring the right half-plane zero point or adding the time-delay, it is obtained that the minimum-phase system has the shortest response time. At any time, the cumulative output energy of the minimum phase system is not less than that of the non-minimum phase system. It can be proved that the cumulative output energy of the minimum phase system is closer to time 0 and has the shortest energy delay. And the inverse system of the minimum-phase system is stable, because the stable poles of the inverse system of the minimum phase system is the zeros of the original system which has no unstable zero. Benefiting from these advantages, the minimum-phase system is widely used in signal processing and other related fields, such as state system, design of causal stable digital filter, neural network and calculation and processing of cepstrum and inverse filtering.

Glaria and Goodwin provided a simple parameterization for the stability control of the minimum-phase. However, there are two difficult problems. One of them is that the parameterization of stabilizing controllers proposed by Glaria and Goodwin usually contain improper controllers. In the specific process of use, a proper controller is needed. Second, the internally stability in the system is not parameterized. In order to solve the above problems, Yamada presents a parameterization for the class of all proper stabilizing controllers for linear minimum phase systems. Parametric processing is carried out by using all the stabilizing controllers, such as all stabilization modification of the minimum-phase plants, repetitive control, adaptive control, model feedback control, parallel compensation technology, PI control and PID control. For multiple-input/multiple-output systems, a parameterization of all minimum-phase controllers for multiple-input/multiple-output systems is given, and the research results of these schemes can be extended to multiple-input/multiple-output.

However, for the minimum-phase plants, there is still a problem whether its stability control can be used by the minimum-phase controller. If the stabilizing controller with non-minimum-phase is used, its unstable zeros will cause the transfer function of the closed-loop system to have zeros on its right half plane. This makes the closed-loop control system very sensitive to the disturbance of the external environment, thus affecting the control effect. In addition, if the feedback loop is truncated, that is, it is split into a feedforward, then the instability caused by it will lead to instability. In this way, even though the controlled plant is of minimum-phase, the control system becomes a non-minimum system. If the minimum-phase control is adopted, the target of the minimum-phase will remain unchanged, and the magnitude of sensitivity of the whole system will become small. The lower the sensitivity curve, the greater the damping to external interference. If the minimum-phase controllers of the minimum-phase plants can be parameterized, a new control strategy for the minimum-phase system can be obtained. Therefore, for the strictly proper controlled plants with minimum-phase, the minimum-phase controllers must be parameterized.

In this thesis, we propose the parameterization of all stabilizing minimum-phase controllers for minimum-phase proper plants. That is, we consider the parameterization that the stabilizing controller makes minimum-phase plant stable, which the stabilizing controller is of minimum-phase. Analysis of the internal stability and control characteristics of closed-loop system are provided. We also present a design method of the minimum-phase stabilizing controllers that contributes to the construction of a minimum-phase closed-loop system. In addition, we show a numerical example to illustrate the characteristics of the proposed design approach. In future work, A design method of a stabilizing minimum-phase controllers for unknown minimum-phase plants will be considered.