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Author(s)	塩田，良治
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Description	Supervisor:示村 悦二郎，情報科学研究科，修士

A design method for the continuous-time modified repetitive control systems

Ryoji Shiota

School of Information Science
Japan Advanced Institute of Science and Technology

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Abstract

There are many cases in the industrial robot manipulator or machine tools, where a repetitive action of the given pattern is required. In that occasion, the high precision of the tracking action is required. One of the direct solution for this requirement is to use a high gain feedback. However the vibration is induced with a high gain, and there is a limit of precision by this method.

For these applications where the fixed pattern of motion is repeated periodically, the repetitive control is considered to be effective. The repetitive control is a servomechanism where the reference input is a periodic function, and a control input is formed by the control error and control input of the previous period.

Let a control object be a strictly proper. Then the repetitive control system can not be exponentially stable. This is caused by the unrealistic demand of tracking to any periodic signal, which contains arbitrarily high-frequency modes. Indeed, it is natural to expect that the stability condition can be relaxed by giving up the error in a higher frequency range. This leads to the idea of the modified repetitive control systems.

However, there is a tradeoff between stability and tracking precision in the design method for the modified repetitive control systems. Now, a steady state error has to be made as small as possible. It is necessary to take a stable compensator in such a way that it is close to the value of one.

The technique of the Kalman filter together with the perfect regulation can be used in a usual design method, because the stability condition is closely related to the optimality condition of the Kalman filter or of the optimal regulation. Let ρ be the parameter for the

perfect regulation. If the squared integral of the output converges to zero as ρ increases, we say that the control law attains the perfect regulation for (C, A, B), we simple write $K'_\rho \overset{\text{p.r.}}{\to} (C, A, B)$.

However, the index for a design parameter is not clear. This is the fault of the perfect regulation that the relations between the design parameters and the performance of the system is not clear. This paper is a change for the better this point as follows.

The weighting coefficient of the perfect regulation is determined by using the turn over method. First, it is shown that the control law attains the perfect regulation for $(C, A + kI, B)$. Second, it is shown that the control law is invariant; i.e. if we replace A by $A + kI$, the control law is invariant. We conclud that $K'_\rho \overset{\text{p.r.}}{\to} (C, A + kI, B)$ for a scaler k > 0 implies $K'_\rho \overset{\text{p.r.}}{\to} (C, A, B)$. This fact suggests that is used in what follows. The weighting coefficient of the perfect regulation can be derived by using the turn over method. But, if there exist the transmission zeros of (C, A, B), the control law does not attain the perfect regulation for (C, A, B). So, the parameter of the turn over method should be chosen by taking it into account the transmission zeros of (C, A, B). An example shows that the proposed method is effective. The closed-loop response to the initial state is sluggish for the small value of the parameter ρ. But when we increase ρ, the response approaches to the one designed by the usual method.

The class of a low-pass filter is a strictly proper function. This low-pass filter may be realized by a simple first-order system $q(s) = 1/(1+Ts)$, $T > 0$, for example. Hence, the condition for the stability of the modified repetitive control system is derived.

From the above result, a low-pass filter is determined by using the parameter ρ and k, where ρ is the parameter of the perfect regulation, k is the parameter of the turn over method. Furthermore, a steady state error is made as small as possible. Simulation results show that the proposed method is effective.

The proposed method can induce a steady state error of the modified repetitive control systems for smaller value of ρ. But the performance of the system designed by this method is as good as of designed by the usual method for a greater value of ρ.