387g Active Disturbance Rejection Control (Adrc) - Application to Nonlinear Cstr

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In recent years significant research has focused on process control strategies which rely heavily on process models. Generally, it takes a great deal of effort to obtain an accurate dynamic model, especially if the process is nonlinear. The task of modeling and prediction is also compounded by model parameters subject to changes over time and unpredictable disturbances. One can not guarantee that an accurate model is always available. Therefore, it is worthwhile to look at alternatives to model based control techniques and attempt to combine them with existing process control techniques. Active Disturbance Rejection Control (ADRC), as a design framework, represents a departure from classical as well as modern control theory (Han, 1999). The principle of ADRC is to adopt a very simple model structure and treat most of the process dynamics as unknown and hence dealt with as an overall disturbance (Gao et al., 2001). Essentially the process is modeled as a pure integrator. Then the disturbance is actively tracked or estimated. and compensated for in the control law. Thus this methodology greatly reduces the dependence on the model and it provides a powerful alternative to the control of processes with uncertain and time varying dynamics, as well as frequently changing disturbances. The central theme of ADRC is real-time estimation of dynamics as an overall disturbance. The Extended State Observer (ESO) has been widely used in ADRC framework. Unlike most existing observers, ESO adds another dimension to the system instead of reducing the system order. The added variable is the overall disturbance. The control law and the disturbance observer were quite complicated initially with many controller parameters to be adjusted, or tuned. Gao (2003) proposed an efficient parameterization approach, which reduces controller tuning to the adjustment of controller and observer bandwidth, which is easily understood by practioners. This makes ADRC not only powerful but also easy to use, a key characteristic valued by control engineers. Controller design by ADRC is also greatly simplified since one only needs to deal with a pure integrator system. For example, a proportional controller is required for a first order systems and a PD controller could be used to control second order systems. ADRC has shown significant advantages when dealing with the nonlinear systems without an accurate model or with time varying parameters. The ensuing successful applications of ADRC in motion control of manufacturing processes, aircraft engine control, space power system, and web tension regulation, etc. demonstrated the potential of this novel methodology (Gao et al., 2001). This paper attempts to familiarize the chemical engineering audience with basic principles of ADRC. Then, two simulations of CSTRs are studied as representative nonlinear process control problems in Chemical Engineering. The first CSTR problem is simulated by a nonlinear model and the the middle unstable equilibrium state is used as the set-point (Adeebekun, 1996). The performance of ADRC is compared to an output feedback controller and a PID controller. ADRC is shown to exhibit superior performance in robustness. Compared to the other control strategies, the controller design by ADRC is shown to be much simpler. The second CSTR has two time varying parameters which shift the process dynamics over the time (Nikravesh et al., 2000). The ADRC is compared to PID and linear Model Predictive Control (MPC). It demonstrates that ADRC has better performance in setpoint tracking and disturbance rejection even with large changes in the time varying parameters. The presentation will discuss the applicability of ADRC framework to nonlinear chemical process control problems. The comparison with MPC shows computational advantages for real-time implementations and ease of tuning the controllers. On the otherhand, the disturbance estimation by ESO requires fairly rapid sampling of process data, which can pose a problem in chemical process control systems unlike their counterparts in electrical systems. These limitations of ADRC are discussed and possible combinations of ADRC with other process control techniques are proposed.

References:

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