Recent Development of Process Control Technology through Industry-University Collaboration in Japan

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Abstract

Novel techniques are born routinely in the academia, but it is always pointed out that there is a gap between theory and practice and the gap has to be bridged. Is it possible to realize gap-free technology development? The answer is yes if industrial engineers provide their problems without concealment and researchers make a resolution to tackle such problems without trivializing them. This paper aims to introduce the recent technology development in chemical process control achieved through industry-university collaboration in Japan.

A task force was launched in Japan in 2007 to sift through problems regarding process control and investigate solutions. The task force, named "Workshop No.27 Process Control Technology," consists of 32 engineers from industry and 12 researchers from universities. It is supported by the 143rd committee on process systems engineering, the Japan Society for the Promotion of Science (JSPS). Since 2007, the following topics have been investigated by the members: 1) practical closed-loop system identification, 2) practical tuning techniques of PID controllers, 3) systematization of the control performance improvement activity based on control performance assessment, 4) control system design from the viewpoint of plant-wide control, 5) evaluation and maintenance of model predictive control, and 6) design and maintenance of soft-sensors. Most of these topics are also covered by the status report of the IFAC Coordinating Committee 6 [Dochain *et al.*, 2008]. These are key issues not only in the Japanese chemical industry but also internationally. In addition, Workshop No.27 sent a questionnaire to member companies of the JSPS 143rd committee on their process control applications including model predictive control (MPC) and soft-sensors. The results are extremely helpful in clarifying the state of the art in process control in Japan [Kano and Ogawa, 2009, 2010].

In this paper, the following two technologies developed by Workshop No.27 are introduced together with their applications to industrial plants: direct PID/I-PD controller tuning and model-plant mismatch detection for model predictive control. In addition, the results of questionnaire survey is presented.

A typical chemical plant has thousands of control loops whose maintenance is vital to efficient operation of the entire plant. In particular, the tuning of PID controllers is important because the PID control algorithm dominates more than 90% of control loops in the process industry. A conventional approach to tackling this problem is to use an efficient open/closed-loop identification method and reduce the burden of modeling. However, any control system based on an identified model suffers from modeling errors and requires retuning of control parameters. In addition, identification is still one of the critical tasks in control system design. Control engineers and operators would prefer to avoid identification and manual tuning of PID controllers. Recently, several direct tuning methods for PID controllers using operation data under feedback control have been proposed, but they are not practical enough. To solve problems with conventional methods, extended fictitious reference iterative tuning (E-FRIT) was propsoed [Kano and Ogawa, 2009, 2010]. E-FRIT has been successfully applied to a chemical process of Showa Denko, in which the pressure oscillation of a distillation column was greatly reduced after retuning, and a steam temperature control of a boiler

process of Idemitsu Kosan, in which the significant reduction of steam temperature oscillation was achieved. In both applications, the significant reduction of utilities consumption was achieved.

MPC has been widely and successfully applied to various processes in various industries. The benefit of MPC is not only the improvement of the control performance by using model-based control, but also the realization of stable operation close to the optimal point under disturbances by using optimization. In addition, MPC makes it possible to maximize the production rate by making the most use of the capability of the process and to minimize cost through energy conservation by moving the operating condition toward the control limit. The control performance of MPC depends on the accuracy of the process model and the appropriateness of tuning, although MPC has outstanding robustness. The questionnaire survey has clarified that MPC has been widely and successfully implemented in the chemical and petroleum refining industries, but problems still remain to be solved. One of major problems identified is the maintenance of MPC. To keep sufficient control performance and to prevent, or at least cope with, performance deterioration, control engineers need to know the cause of performance deterioration and take effective countermeasures. Since performance deterioration is usually caused by changes in process characteristics, effective re-modeling is the key to success in the maintenance. Obviously, not all sub-models have to be reconstructed. For reducing engineers' burden of re-modeling, it is crucial to identify sub-models that have significant model-plant mismatch and that need to be corrected. In general, MPC systems have tens of manipulated variables and controlled variables, which makes detection of significant model-plant mismatch very important in practice. Recently, a novel method was developed to detect significant model-plant mismatch from routine closed-loop operation data on the basis of the statistical test concept [Kano *et al.*, 2010]. The mismatch detection method has been successfully applied to a distillation process of Mitsubishi Chemical.

In addition, Workshop No.27 developed a dynamic simulator for the benchmark vinyl acetate (VAc) monomer production process [Yumoto *et al.*, 2010]. A rigorous first-principles dynamic model of the VAc process was implemented on the commercial software package: Visual Modeler (Omega Simulation Co.,Ltd.). The simulator's high performance calculation provides an environment where feasibility and performance of designed control systems can be efficiently evaluated without sacrificing high fidelity of the process model. The developed simulator will be made available in the public domain with a free limited license of Visual Modeler; it is useful for researchers who would like to validate new control or monitoring techniques in a realistic situation.

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