Chapter 51
Adaptive and Neural pH Neutralization for Strong Acid–Strong Base System

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ABSTRACT

The control of pH is of great importance in chemical processes, biotechnological industries, and many other areas. High performance and robust control of pH neutralization is difficult to achieve due to the nonlinear and time-varying process characteristics. The process gain varies at higher order of magnitude over a small range of pH. This chapter uses the adaptive and neural control techniques for the pH neutralization process for a strong acid-strong base system. The simulation results are analyzed to show that an adaptive controller can be perfectly tuned and a properly trained neural network controller may outperform an adaptive controller.

INTRODUCTION

Effective modeling of a pH neutralization plant is not a recent issue. However, due to the nonlinear characteristics and complexity of this type of system, research on how to provide a good dynamic model of pH neutralization process, which was first started in the 1970's or earlier, still continues. The pH process can be mainly classified into four groups and they are strong acid-strong base system, strong acid-weak base system, weak acid-strong base system and weak acid-weak base system. The strong acid-strong base pH process is the most highly nonlinear process among the group. The pH value versus the reagent flow has a logarithmic relationship. Away from neutrality, the process gain is relatively small. Near neutrality where pH = 7, the process gain can be a few

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thousand times higher. Hence it is impossible for a fixed controller like PID to effectively control this process.

pH control is an interesting and challenging research subject which has led to a large number of motivating and interesting published papers. The control of pH process is a classic and difficult nonlinear control problem encountered in the chemical process industry. Various control strategies used for pH control are classified as non-adaptive linear, adaptive linear, model based, non-adaptive non-linear and adaptive nonlinear. For years there has been researches using various control approaches, such as simple PID control, adaptive control, nonlinear linearization control and various model-based control. Conventional control methods rely on the exact mathematical modeling of the plant, which may be tremendously difficult to obtain in many cases.

LITERATURE REVIEW

Ahmmed (2010) illustrated a modified dynamic structure model which takes into account the presence of acid and alkali in the reaction with ions which depend on chemical reactions of acid and alkali concentration feeds. Model simulations indicated that it was capable of predicting reactor performance indicators as well as calculating the changes of ions through the chemical reaction.

Thomas et al., (1972) presented a rigorous and generally applicable method of deriving dynamic equations for pH in continuous stirred tank reactors (CSTRs). A specific example of neutralizing sodium hydroxide with acetic acid was discussed in detail. Experimental results on a laboratory-sized CSTR verified the accuracy of the derived model. Commonly available linear controllers carry out well in the linear range of the process for which they have been tuned. But they are unsuitable and unstable in nonlinear ranges due to time varying process gain. Hence the linear control designing methods are limited in many real-world processes. The conventional PI or PID controller provides poor controlling performance for pH process and needs frequent tuning of the controller while parameters are not estimated. The PID controllers are tuned based on the highest gain at the equivalence point of pH equal to 7 in order to make a closed loop stable system. Hence the controllers will be working around the neutralization point which results in wasteful consumption of reagents due to process oscillation or sluggish response of the process variable [Shinskey (1996)]. From this it is concluded that linear controlling techniques are not appropriate for highly nonlinear pH process.

Waller and Gustafsson (1983) investigated the fundamental properties of continuous pH control. Their experimental results suggest that taking into account the capacity of the reactor tank during plant design is important in order to have fast and efficient mixing in the tank. Gustafsson and Waller (1992) have discussed the issues in dynamics and control that arise in this nonlinear control applications. Further reviews were also carried out by Gustafsson et al., (1995). The non-adaptive linear PI or PID controller provides poor performance for pH process or requires frequent tuning (which is impractical) of a controller when parameters are uncertain. The sliding mode PID controller has problems of chattering of manipulated variable. Linear model based techniques are not suitable for highly nonlinear pH process. Many nonlinear control methods which use empirical models or rigorous physiochemical models are available. Several control algorithms have been proposed in the literature to design a good pH control system. Many of them use non-linear model-based algorithms combined with some kind of adaptive feature. In this context, the controller design methods usually consider the process nonlinear characteristics. This non-linearity can be seen as a time-varying gain that leads to linear adaptive controllers.

Qinghui and Zongze (2010) stated that it was significant to control pH value rapidly and accurately for neutralization reaction process, which