ABSTRACT

Process engineers use fundamental scientific principles as the basis for mathematical models that characterize the behavior of a chemical process. Symbols are used to represent physical variables such as pressure, temperature, concentration or time. Input information is specified and numerical algorithms are used to solve the models. Process engineers analyze the results of these simulations to make decisions or recommendations regarding the design, operation and control of a process.

Many of the chemical engineering processes are nonlinear. For some, fundamental models based on known physical-chemical relationships are available. But if the process is too complex for a fundamental model, an empirical model which has satisfactory predictive capability of experimental data is developed.

Nonlinear empirical models of complex nonlinear processes like photoelectrocatalytic oxidation of textile dye effluent and electrooxidation of distillery effluent for which fundamental models are not available, were developed using response surface methodology (RSM) and feed forward back propagation artificial neural network (ANN) to predict the experimental results and optimize the processes.

The treatment of procion blue dye effluent using a thin-film photoelectrocatalytic novel reactor is reported. RSM was applied to design the experiments and the optimum operating parameters were determined for chemical oxygen demand (COD) removal and energy consumption. Operating
parameters such as initial effluent concentration, applied charge, and lamp wattage were selected. The COD removal and energy required for treatment were optimized using RSM, and a regression equation was developed for COD removal and energy consumption of photoelectrocatalytic process. The study concludes that the power consumption for the process can be optimized using RSM and that RSM is a good tool for studying combined variables and interaction effects on the response of a process.

The technical feasibility of treating the high strength distillery waste water in an electrochemical flow reactor is presented. The experiments were conducted using oxide coated on expanded titanium (Ti/Ti_{0.7}Ru_{0.3}O_{2}) as anode and stainless steel as cathode in a batch reactor with electrolytic recirculation. Pollutant degradation was measured as COD removal for various operating parameters such as effluent flow rate, current density and supporting electrolyte concentrations. ANN was used for modeling the experimental results. The model has been developed using a feed forward back propagation network with different layers and neurons. It is concluded that the network configuration (3-3-3-1) gives better performance to predict the experimental results and using this network model, COD removal can be predicted quickly and easily.

Some of the nonlinear processes like Van de Vusse and autocatalytic reaction in isothermal continuous stirred tank reactors (CSTR), continuous stirred tank bioreactors (CSTBR) with monod and substrate inhibition specific growth rates kinetics and penicillin fermenter and nonideal mixing isothermal and nonisothermal CSTR are represented by initial value nonlinear ordinary differential equations with necessary input data to solve the equations. The methods reported by various authors for the design of
control strategy for such systems involves linearizing the nonlinear process around a desired steady state operating point and representing these systems by first or second order plus delay transfer functions with identification of model parameters and then applying a complex control theory to this transfer function models to obtain proportional integral (PI)/proportional integral derivative (PID) controller tuning parameters. A linear or nonlinear controller based on a linear model may reasonably give good results if the process has mild nonlinearity. But when a process shows strong nonlinear behavior, a linear model may be inadequate. Since the systems considered exhibit severe nonlinearities, the control strategy developed on linearized transfer function models can invariably hold good only for a small region around the operating steady state point.

Hence a simple alternate tuning method is presented for control of these nonlinear chemical processes. The physically changeable manipulated variable in real time by linear or equal percentage control valve was carefully selected. PI/PID controllers are very common in industrial environment and more than 90% of control loops in industries are PI/PID. Hence the design of PI/PID controllers with acceptable control performance was attempted and the tuning parameters were computed by simulation of online trial and error tuning method practiced by an instrument mechanic on nonlinear process.
nature and can also be customized to other nonlinear systems exhibiting severe nonlinearities.

To overcome the limitation of PI/PID controllers for nonlinear processes where the process gain is continuously changing, fuzzy and gain scheduling PI/PID controllers have been suggested in the past. In the current study, a new variable gain PID controller of temperature for nonisothermal CSTR to vary the controller settings continuously to compensate for the nonlinearity of the process is presented. A new modified multistage variational iteration method (MMVIM) was implemented to obtain and analyze the dynamics of systems and design of the controller.

First, the analysis of CSTR without controllers by fourth order Runge-Kutta method (RK4M), variational iteration method (VIM), multistage variational iteration method (MVIM) and MMVIM ascertained the effectiveness of MMVIM and MVIM over VIM to obtain open loop response within a large time span by comparing with benchmark RK4M. The closed loop performance of CSTR by MMVIM, MVIM and RK4M with PID controllers for reactor temperature and reactant concentration was studied and observed that the performance of MMVIM is exactly matching RK4M in comparison to the poor performance of MVIM. Hence MMVIM was selected for further analysis and conventional PID controller for reactor temperature was converted into a nonlinear variable gain controller adopting a new tuning technique. It is shown that the variable gain controller designed by adopting the new tuning technique improves the performance significantly over the conventional PID controller.