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Experimental Control of Chemical Process for Undergraduate Student Education

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Abstract: - This paper presents experimental study of the control theory for chemical process. pH process is nonlinear system, has been examined with frequency analysis. By means of this implementation, control theory may be understandable issue according to the undergraduate students. Process control is an important factor for an undergraduate education that provides hands-on training in the application of process control to real processes. On the other hand fundamentals of process control need to be taught in a more practical and tangible way which is an educational necessity. So the students can develop manual skill by means of these experiments. Additionally they can construct relation between real process and control theory. Practice in control theory can greatly benefit the learning process. Practice motivates, promotes critical thinking and facilitates understanding in the use and limitations of the theory.

Key-Words: - Control education, educational equipment, undergraduate students, process control, control theory, pH process.

1 Introduction

Classical and modern methods of control can be introduced with appropriate tools that reduce the work in computation and drawing examples in classroom demonstrations, exercises, projects and laboratory work [1]. Practice in control theory can greatly help the learning process. So by means of practice, students will be motivated, promote critical thinking, facilitate understanding in the use and limitations of the theory. Additionally practice prepares students for the challenges of the professional world [2]. Control emerged with development of classical control methods in 1930s and 1940s. The major applications initially were in the military arena, then extended quickly to manufacturing, aerospace, electromechanical devices, process control and so on [3]. Control has an essential role in the development of technologies such as power, communications, transportation and manufacturing [4]. Classical control methods were developed between the 1940's and 1960's in the mechanical and electromechanical engineering disciplines [5]. Given the limitation of computer hardware and software at that time, it was impractical to solve large numbers of higher-order differential equations. Furthermore, mechanical and electromechanical systems are typically linear and have little dead time. So analytical and graphical techniques as Laplace and Fourier Transforms, Bode, Nichols and Nyquist frequency methods, Root locus analysis have been developed. For implementation the methods require physical meaning for adjust the system in order to achieve control [5]. For this reason pH process which is nonlinear system, has been examined using frequency analysis by practice for understandable issue. This process has been examined according to the control education for undergraduate students. Process control is an important factor for an undergraduate education. This provides hands-on training in the application of process control to real processes. On the other hand, fundamentals of process control need to be taught in a more practical and tangible way which is an academic requirement. Control education clearly needs to do better [5]. According to the classical approach, the frequency response methods have been used for control education, which were originally developed as pen and paper methods for the modeling of process systems [6]. Hence, for system modeling pH process is realized by transfer functions as shown in Fig.1.

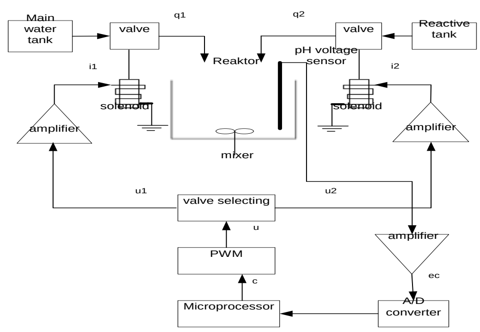

Fig.1. Control system of pH process

2 Characteristic of pH Process

The frequency domain analysis is used in controller design because it obtains easy calculation for complex and dead time systems [14]. So, the frequency response has been used according to controller coefficients, speed response of electrode, stirred time, transfer delay, and sampling time for the pH process. Maximum gain of the system is computed according to the selected control coefficients. These coefficients are the function of current pH value. The coefficients are calculated for all pH regions and loaded in EPROM. Classification and comparison features of microprocessor have been used. When system works, microprocessor reads the current coefficient which is the instant function of pH, reduces spending time and error probability. Additionally, the small time constant or multi input system could be controlled. To realize the pH process control, first the dynamic model is constituted, which gives experimental or theoretical process, and the controller is planned, which supplies efficient performance when the selected model works. And finally, the controller is adjusted according to the process. Mathematical model of the system is constituted for control system's stability and analyzed in frequency domain in order to keep the dynamic performance at a desired level. Control coefficients and maximum system gain are computed using selected control criterions. pH process is quite nonlinear system. So the experimental results and controller coefficient values are computed according to pH process. Gain of the controller changes according to pH. By means of this change static and dynamic performance will be at a definite level. Depending on the pH of liquid in tank, pH voltage sensor generates a voltage value. This voltage value is increased by the amplifier and streamed to the A/D converter and then applied to the microprocessor. Microprocessor finds the pH value using voltage-pH transform table. This pH value is compared with the desired pH value. Coefficient of the PWM (pulse width modulation) is computed using the control program. The valve is checked by the control program. Microprocessor based pH controller is shown in Fig.2. By means of this controller, the students can see the effects of the parameters on the systems. Additionally, while the students are studying with this process, they have an idea about the converter, microprocessor and PWM.

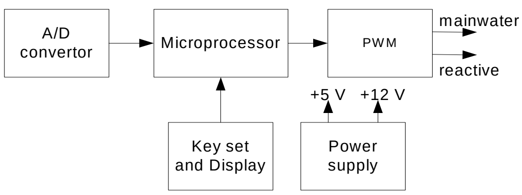

Fig.2. Microprocessor based pH controller

3 System Modeling

Process control has been based on the mathematics. This includes the modeling of process dynamics using differential equations and their transforms, and the use of a variety of analytical techniques based primarily on the Laplace and frequency domains. The AICHE did a research about perspective of the students for control courses. As a result of this inquiry, students have complained that control courses are too abstract and mathematical; hence it is difficult to grasp that between the mathematics of control and its practice. A common quote from control students is "I haven't used a laplace transform since I graduated." [7]. In control education, the classical methods have been to explain as an experimental study. So the student can then easily indulge in "what if" studies to find an optimal control structure and set of control parameters for the controllers the fundamental aim of process control [5]. According to this aim, pH process has been constituted.

The practical advantage of identifying nonlinear systems like pH process using a block–structured approach is that the linear and nonlinear elements can be separated from the system and individually modeled from process input- output data [8]. In order to control the pH in tank, the pH value needs to be measured and compared with the desired pH value. The stability of the system depends on the correct measurement of pH. In general pH sensor and the amplifier that pH sensor connected, shows reaction with τe time constant for pH variation. This τe (time constant) is a function of current pH. The solution is stirred by mixer in the tank. Although the solution is stirred enough, the changes in pH can not be transferred immediately. So the system has a transfer delay as shown time delay constant τd. This delay occurs with mixed time constant τm at the same time. The effect of these constants in the transfer function is computed by the students. After this event they can understand the relation between the mathematics relation and the process system while practicing on the system. Analog signal which measured by the pH voltage sensor is converted to digital signal by A/D converter with sample frequency (1/Ts) and streamed to microprocessor. Current pH is compared with the desired pH value. If current pH value is under desired pH value, the reactor is not active. When current pH value is over the desired value, the main water valve is activated by means of microprocessor, PWM and selecting valve. Valves operate on-off and it is fast enough compared with the system.

When the students try to supply control loop and transfer function, they can control the system easily according to the parameters as explained above. So the students can interpret the transfer function easily.

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Control blocks are examined separately and all blocks have transfer functions. In Fig.3, the pH control loop is presented. Control blocks are examined separately and all blocks have transfer functions. It can be seen immediately that, from a learning perspective, the block diagram of transfer function in Fig. 3 does not bear an obvious relationship to the real plant in Fig1.

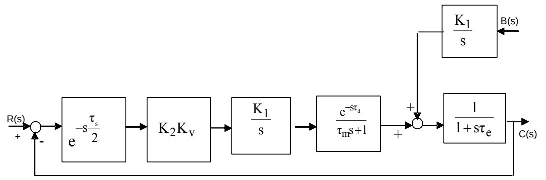

Fig.3. pH control loop

Open loop transfer function for Fig.3 is presented in Eqs. (1).

$$H(s) = \left[\frac{K_1 K_2 K_V e^{-s\left[\tau_d + \frac{T_s}{2}\right]}}{s(1+s\tau_m)(1+s\tau_e)} \right] \qquad (1)$$

The resulting gain change is unpredictable and this is what makes pH control difficult [9,10]. K1 changes according to current pH. For this reason, main water titrates with reactive and K1 values are calculated. For titration curve, main water is put into beaker and reactive is added by means of burette. So solution is stirred with magnetic mixer. After every reactive addition, pH is measured and registered. In experiment 100 ml solution of borax (5g. Na2B4O7.10H2O) has been titrated with sulphuric acid (1N H2SO4) at 28.6ºC. So the students can develop manual skill by means of these experiments. And frequency response of the system has been examined according to the controller coefficients such as response speed of electrode, mixed time, transfer delay, and sampling time. So the students can see the effects of the parameters by the simulation and implementation. In this study frequency domain analysis is used in designing controller. By using frequency response of open loop transfer function, closed loop stability can be established.

The flexibility is offered by open laboratories for applying both traditional control theory and modern approaches on real problems. Open laboratory means where the same equipment is used for extensive number of experiments different in nature [11]. Additionally, the microprocessor based controller which is constructed for pH process, can be used for some other control algorithms to adapt this work to other fields. Furthermore, the empty inputs of A/D converter can be used for measuring such as temperature, and flow speed of liquid. More than one reactor can be controlled by changing the control program. So these studies can be implemented by the students. This kind of work is very useful for the development of the students' opinion. When the students examine the process system, they may ask how to perform a full analysis of the process behavior in both open and closed loop, including comments on the linearity, order of response, and better control strategies for the pH process system. Control course should have some aim, operation, control components; that will motivate the students to learn the fundamentals and applications [12].

4 Perspective of Control Education

Process control education at the undergraduate level is often a difficult task due to the significant theoretical content of courses. Additionally, undergraduate students have limited experience with dynamic systems. During the past decade, there has been a main impetus in engineering education to change from a teacher-centred lecture environment to a student-centred learning environment. Already the student is central in educational process according to the total quality management. Learning process is influenced by a number of factors which are instructor who is responsible for process of classroom lectures, hands on training, use of process. Using hands on experimental study is closely attached to the traditional process control lecture course that allows students to see application to real world systems and attractive the theoretical content of the lecture course. Experimental studies for undergraduate education have been shown to be beneficial to the educational process [13]. On the other hand, the technology plays a significant role in learning and teaching goals, because the general direction of learning and teaching process is determined by defining the industry needs.

5 Conclusion

The focus of this article is the process control education approach for undergraduate students. Control education is an area where permanent development is important. Process control has been based on the mathematics. Fundamentals of process control need to be taught in a more practical and tangible way which is an educational necessity. So control theory has been explained as an experimental study in control education. By means of this study students can grasp between the mathematics of control and its practice. Process control is an important factor for an undergraduate education. This provides hands-on training in the application of process control to real processes. It is known that undergraduate students need more practical control experience. Practice can greatly help the learning process in control theory. So by means of practice, students will be motivated, promote critical thinking, facilitate understanding in use and limitations of the theory. Additionally experimental study prepares students for the challenges of the professional world.

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