

Intelligent Control of pH for Juice Clarification

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Abstract

In the process of manufacturing white consumption sugar, the clarification of juice in the juice clarifier is a very important task. At the clarifier, raw juice is treated with milk of lime and then with Sulphur Dioxide for maintaining the treated juice pH around a pre-determined value. The lime sulphitation pH control system provides very effective clarification for the liquid phase reaction which improves the quality of sugar produced. The mixed juice from the mills contains soluble and non-soluble suspended non-sugars. These impurities are to be precipitated by the judicious and controlled addition of milk of lime and subsequent neutralization by Sulphur Dioxide gas. In this paper, a hybrid Fuzzy logic P+I control of pH in the juice clarifier is attempted. The Fuzzy controller is very successful in handling such systems with non-linearities and various complexities without having to develop their mathematical models in an explicit form using any integral, differential or complex mathematical equations. At the same time all the advantages of the conventional P+I controllers are retained. The simulation has been performed in the MATLAB environment using Simulink and Fuzzy Logic Toolbox. The results show that the hybrid controller is more efficient in tracking the set points and is more stable when compared with P+I controller.

Keywords: Fuzzy Logic Control, Juice Clarifier, Lime Sulphitation pH Control, P+I Controller.

1. Introduction

Systems for pH control can be divided into two types, those where pH control is incidental to carrying out the main reaction and those where the equipment serves only to mix a reagent and process stream to give a certain pH[1]. Fermentation is an example of the first type, and because of the large hold up of solution and slow disappearance of reagent, pH control is fairly easy and on-off control is usually adequate.

The pH control in a juice clarifier discussed in this paper is an example of the second and more difficult type of problem. In this application, the non linear change in the pH with the reagent flow makes close control of pH difficult. A change in the set point can change the process gain and optimum controller gain several fold and perhaps lead to unstable oscillations. Also the system used for pH control have to cope with severe load changes resulting from changes in concentration and change in flow. Large load changes affect the process gain and may even alter the time constants of the system, which makes it very difficult to design a control system that is moderately fast yet stable for all conditions. For such systems, controlling with classical controllers like a Proportional-Integral (P+I) controller is really difficult. On the contrary, a Fuzzy controller is very successful in handling such systems with non-linearities and various complexities. The Fuzzy controllers are capable of utilizing knowledge elicited from human operators[2]. This is crucial in control problems for which it is difficult or even impossible to construct precise mathematical models. Fuzzy logic systems can map the physical non-linear relation of input-output model without a precise mathematical formula.

In this paper, a Hybrid Fuzzy logic P+I Controller is designed for the juice clarifier. The performance of this controller is compared with the classical P+I controller.

2. Clarifier and pH Control

The mixed juice from the mills contains soluble and nonsoluble suspended nonsugars. These impurities are to be precipitated by the judicious and controlled addition of milk of lime and subsequent neutralization by Sulphur Dioxide gas to maintain the pH around a preset value. In earlier pH control systems, it was assumed that the flow of SO_2 is constant and SO_2 flow control was hence not attempted. But later the need was felt for an online continuous lime and SO_2 flow control. A majority of the sugar factories in India are based on double sulphitation process for clarifying mixed juices. This process demands controlled addition of milk of lime (Figure 1) and Sulphur Dioxide (Figure 2) depending upon the pH of the mixed juice[4].

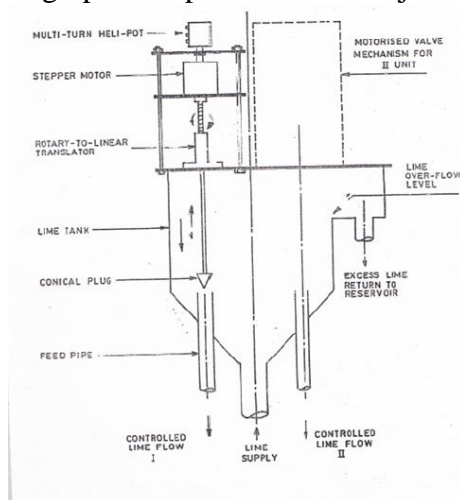


Fig. 1: Lime Flow Control Valve.

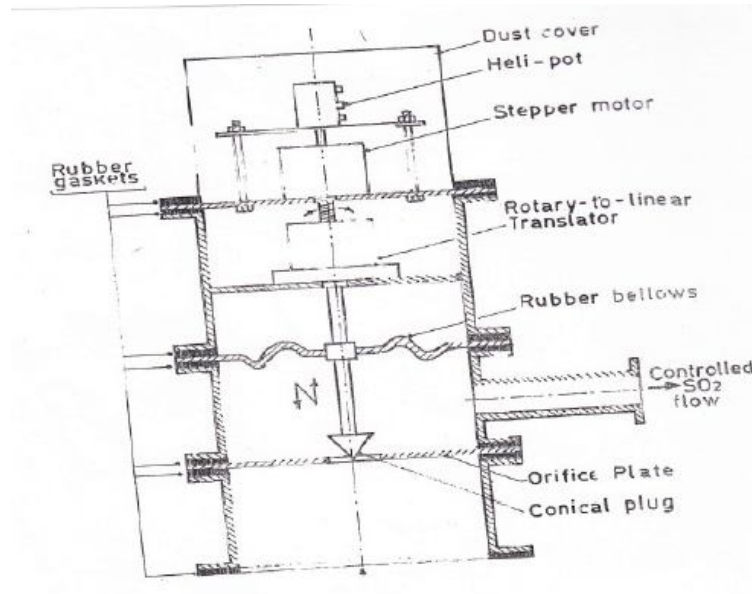


Fig. 2: SO₂ Flow Rate Control Valve.

3. Classical P+I Controller

The block diagram of the pH neutralization in a juice clarifier is shown in (Figure 3). The process is simulated in MATLAB using Simulink. Two control valves are included in the simulation, one for controlling the flow of milk of lime and the later for control of flow of SO₂ into the raw juice[7].

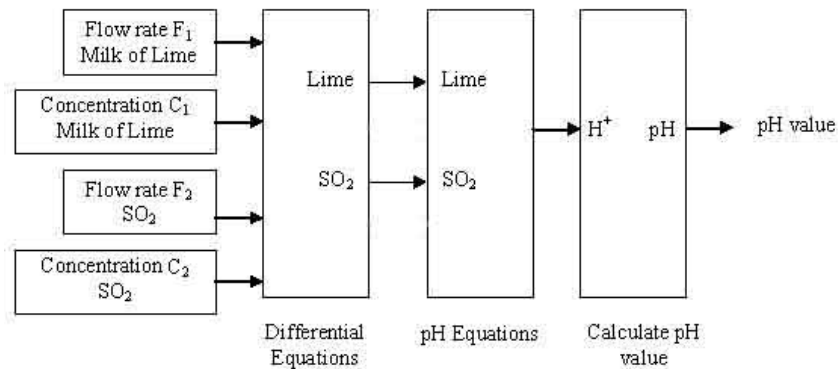


Fig. 3: Mathematical model of pH neutralization.

The classical approach and method most widely used in practice for establishing appropriate values for the control parameters of a PID controller is the Ziegler–Nichols tuning method. Although the approach is a proven method, in the case of highly non linear systems a modified trial and error procedure to find the most appropriate parameter settings is required[8].

4. Implementation of Hybrid Fuzzy Logic P+I Controller

In general, Fuzzy controllers are general expert systems. Its basic configuration comprises Fuzzification interface, Rule base, Inference mechanism and Defuzzification interface[6]. Figure 4 shows the logical diagram of Fuzzy logic P+I controller[8]. The set point of the desired pH value is entered manually while other process control variables are controlled automatically based on the information (feedback) coming from the plant output. The job of the Fuzzy logic controller is to maintain the corresponding pH value while manipulating the process control variables. When the current pH value is less than the desired value, Fuzzy logic controller sets a new point for the P+I valve flow rate controller[7]. The new value of current set point depends upon the difference between the current pH value of effluent juice and the desired value.

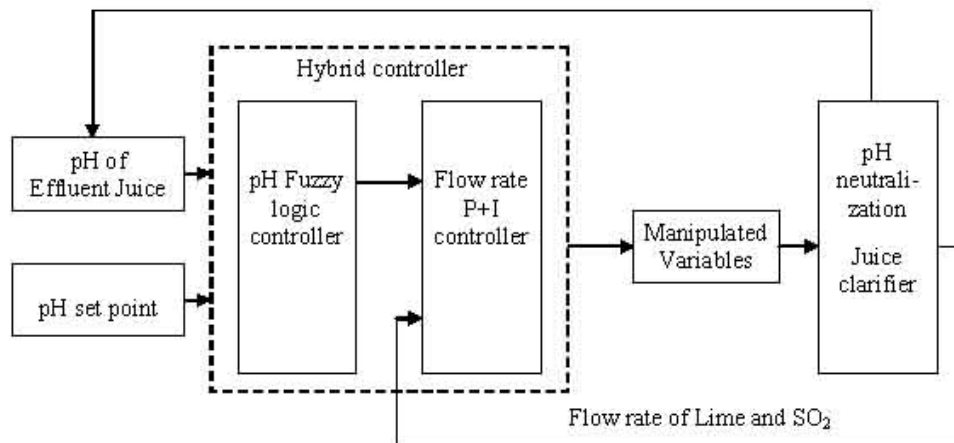


Fig. 4: Logical diagram of Fuzzy logic P+I controller.

Figure 5 and 6 show the membership functions for the input and output sets respectively[8]. The input set is the error in the pH value of the effluent juice. Output set in this case determines the output for P+I controller (whether to increase the pH value by increasing the flow rate of milk of lime or to decrease the pH value by increasing the flow rate of SO_2).

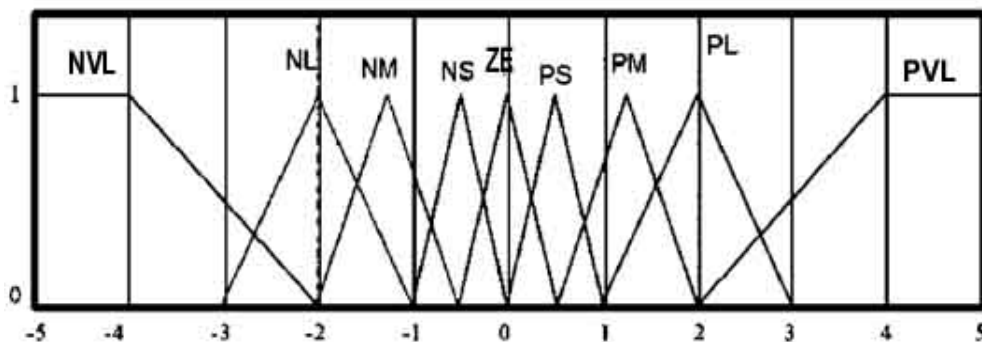


Fig. 5: Membership function of input set.

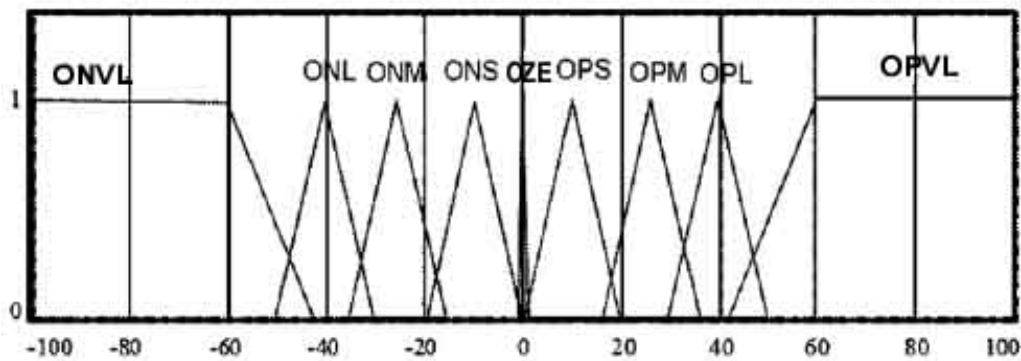


Fig. 6: Membership function of output set.

Table 1 shows the Rule Base which defines the relationship between the input set and output set parameters[7].

Table 1: IF–THEN Rule Statement Description

| Error in pH | Manipulated variable for P+I controller |
|-------------|---|
| NVL | ONVL |
| NL | ONL |
| NM | ONM |
| NS | ONS |
| ZE | OZE |
| PS | OPS |
| PM | OPM |
| PL | OPL |
| PVL | OPVL |

5. Results and Inferences

Regarding the set value of pH of the clarified juice, no fixed universal values are available. It varies with the type of juice that is being handled at the clarifier. It is desirable to maintain uniform pH since rapid changes in pH are likely to cause secondary precipitation in the juice[4]. In our simulation a set value of 7.00 pH is selected.

Servo and Regulator Problems. For every feedback control system, we can distinguish two types of control problems: the Servo problem and the Regulator problem[3]. In the Servo problem, the set value of the controlled variable undergoes a change while the load disturbance remaining unchanged. On the contrary, in the Regulator problem, the load disturbance changes with the set point remaining unchanged. To study the Servo response, a step increase in the set value of pH is done from 7.00 to 8.00 at 200 sec, 8.00 to 10.00 at 1500 sec, 10.00 to 9.00 at 800 sec, 9.00 to 6.00 at 1200 sec and then back to 7.00 at 500 sec. Similarly in the Regulator problem, the set value is kept constant and a load disturbance is applied by changing

the influent flow of raw juice[5]. It is increased by 2%, 4%, 6%, 8% and 10% from its nominal value at 200sec, 500 sec, 800 sec, 1200 sec and 1500 sec respectively.

Integral Square Error It is observed that the steady state response of the process under Hybrid controller is much better than that under P+I controller in both the Servo problem and Regulator problem. As a dynamic performance criterion, the Integral Square Error (ISE) has been calculated[5] for the process response under Hybrid controller and P+I controller. The calculated value of ISE is found to be much less for Hybrid controller in Regulator response and slightly less in case of Servo response when compared with the P+I controller.

6. Conclusion

The scope of this paper was to design a classical P+I controller and a Hybrid Fuzzy logic P+I controller for the simulated process. As such, no hardware implementation is carried out. Hence typical problems like pH electrode lag, choking of feed valves and feed channels with lime etc. are not given attention. The main objective of this work was to demonstrate that the Hybrid controllers is much better when compared to classical controllers to control those processes which are highly non-linear and where the analytical model is not well known.

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