Temperature Control of Heat Exchanger Using Fuzzy Logic Controller

Aravind R. Varma and Dr.V.O. Rejini

Abstract--- Fuzzy logic controllers are useful in chemical processes where non-linearity is very high. Fuzzy logic controllers are based on approximate values called linguistic variables. These linguistic variables are not sharp and precise. Fuzzy logic uses the concepts of fuzzy sets whose value varies from 0 to 1. The main advantages of using Fuzzy logic are reduction in rise time, settling time, overshoot etc and improved robustness and efficiency in noisy environment. Membership functions are used for inputs and outputs. Fuzzy logic controllers are capable of eliminating errors in modeling of the process. Heat exchangers are used for heating or cooling process fluids. Heat exchangers use heating elements like steam, hot water or some other materials to supply heat to process fluid. Heat exchangers can be a shell and tube heat exchanger, Plate heat exchanger, Double pipe etc. Temperature control can be achieved my manipulating the flow of heating fluid. Disturbances that can affect the process are flow of process liquid and inlet temperature. Heat exchanger system is widely used in chemical plants because it can sustain wide range of temperature and Pressure. The main purpose of a heat exchanger system is to transfer heat from a hot fluid to a cooler fluid, so temperature control of outlet fluid is of prime importance.

Keywords--- Fuzzy Logic Control, Heat Exchanger, Mathematical model, I/P Convertor, Control valve, Thermocouple, PI Control

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I. INTRODUCTION

Chemical processes usually introduce high non-linearity and the parameters of these processes are time variant in nature. The dead time introduced by these processes is considerable. In these cases where non-linearity is high conventional controllers can be replaced by Fuzzy logic controllers. In fuzzy logic control precise knowledge about the system is not required. Rules developed are approximate in nature rather than exact.

It emulates the ability to reason and uses approximate data to find solution. Fuzzy logic control is a knowledge based control that works on the rules that are created based on the knowledge of experts. "If-Then" principle is used for the creation of rules.

Advantages of using fuzzy logic are the control system can be made robust as it doesn't require precise, noise free inputs. Failure of system components doesn't cause system to fail. Flexibility of the system is another feature that helps in modifying the rules.

Fuzzy rules can be defined for any number of inputs and outputs. Complexity of defining rules increase with increase in number of inputs and It would be better to break the system into smaller parts are several small fuzzy logic modules can be created each with limited functionalities.

Fuzzy logic model can be used for non-linear functions of arbitrary complexity. Most commonly used membership functions are triangular, rectangular, trapezoidal membership functions. Each membership functions are provided with linguistic variables.

In practice, all chemical process involves production or absorption of energy in the form of heat. Heat exchanger is commonly used in a chemical process to transfer heat from the hot fluid through a solid wall to a cooler fluid. There are different types of heat exchanger used in the industry but most of the industry used heat exchanger system. Heat exchangers are probably the most common types of heat exchanger applicable for wide range of operating temperature and pressure.

They have larger ration of heat transfer surface to volume than double pipe heat exchangers, and they are easy to manufacture in large variety of sizes and configuration. They can operate at high pressure, and their construction facilitates disassembly for periodic maintenance and cleaning. Heat exchanger find widespread used in refrigeration, power generation, heating and air-conditioning, chemical process, manufacturing, and medical application. A heat exchanger is an extension of the double pipe configuration. Instead of single pipe with tubes enclosed within a cylindrical shell. In the heat exchanger one fluid flows through a tubes and a second fluid flows through within the space between the tubes and shell. This paper reports a work that considers a heat exchanger and builds a single-input single outputs model of the system with the help of experimental data available.

II. PROCESS MODEL

A typical interacting chemical process for heating consists of a chemical reactors and a heat exchanger system. The process fluid which is the output of the chemical reactor is stored in the storage tank. The storage tank supplies the fluid to the heat exchanger system. The heat exchanger heats up the fluid to a desired set point using super heated steam at 180 C supplied from the boiler. The storage tank supplies the process fluid to a heat exchanger system using a pump and a non returning valve. The super heated steam comes from the boiler and flows through the tubes, whereas the process fluids flow through the shells of the heat exchanger system. After the steams heat up the process fluid, the condensed steam at 100 C goes out of the heat exchanger system. There is also a path of non condensed steam to go out of the shell and heat exchanger system in order to avoid the blocking of the heat exchanger.

Different assumptions have been considered in this research paper. The assumptions made are

1. The inflow and the outflow rate of fluid are same, so that the fluid level is maintained constant in the heat exchanger.
2. The second assumption is the heat storage capacity of the insulating wall is negligible.
3. In this feedback process control loop, the controller is reverse acting, the valve used is of air to open (Fail-close) type.
4. A thermocouple is used as the sensing element, which is implemented in the feedback path.

The temperature of the outgoing fluid is measured by the thermocouple and the output of the thermocouple (voltage) is sent to the transmitter unit, which eventually converts the thermocouple output to a standardized signal in the range of 4-20 mA. This output of the transmitter unit is given to the controller unit. The controller implements the control algorithm, compares the output with the set point and then gives necessary command to the final control element via the actuator unit.

The actuator unit is a current to pressure converter and the final control unit is an air to open (fail-close) valve. The actuator unit takes the controller output in the range of 4-20 mA and converts it in to a standardized pressure signal, i.e. in the range of 3-15 psig. The valve actuates according to the controller decisions. The transfer function of the process is of the form $\frac{K.e^{T_d s}}{Ts+1}$

K=50, T_d=3.6, T=30 from experimental data.

Control valve has Transfer Function $\frac{K.}{Ts+1}$

K=0.13, T=3 from Experimental Data.

I/P has a gain of 0.75.

Thermocouple has Transfer Function of the form

$$\frac{K.}{Ts+1}$$. K=0.16, T=10 from Experimental Data.

III. PI CONTROL OF THE PROCESS

$$P(t)= K_p\, e(t)+ K_p/T_I \int e(t) + P(0)$$

Propotional control action produces a control signal that is propotional to error signal. Integral action produces signal that accumulates present and past errors. Propotional action improves speed of response and Integral action improves Settling time.

Table 1: Tuning Parameters of PI Controller

Controller	K_P	KI
PI	0.242	0.000001

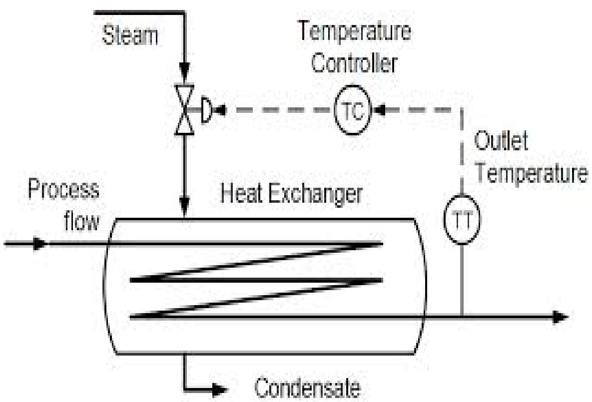

Fig. 1: Control Scheme of Heat Exchanger

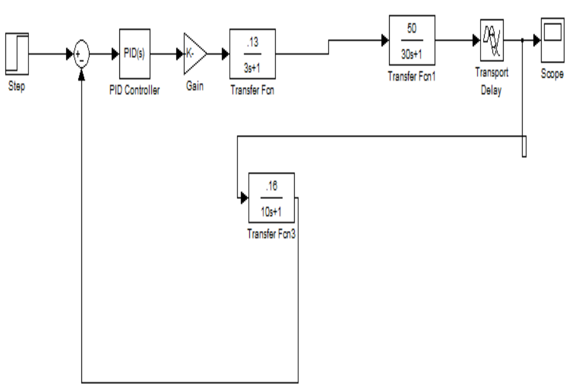

Fig. 2: Block Diagram of PI Control

IV. FUZZY LOGIC CONTROL

Fuzzy logic concept is used in controlling the temperature of a Heat Exchanger. Triangular membership functions are used with 7 linguistic variables. Linguistic variables are very very small (vvs), very small(vs), small(s), zero(z), big(b),very big (vb), very very big(vvb). These linguistic variables are used for error, change of error and output. Error a varies from -10 to 10. Output varies from -1 to 1. Change of error varies from -15 to 11.

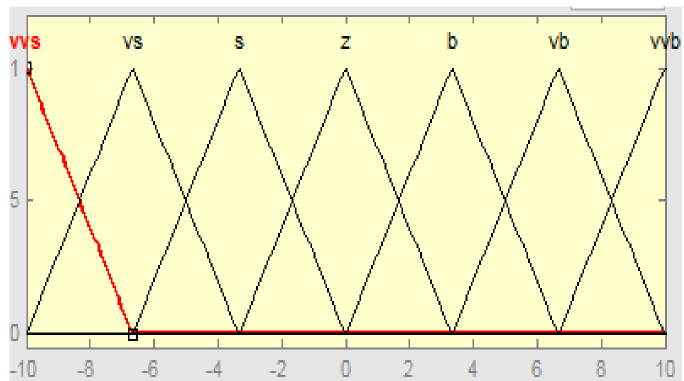

Fig. 3: Membership Function for Error

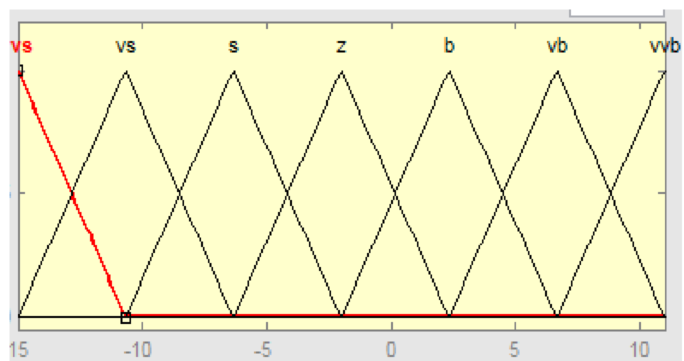

Fig. 4: Membership Function For Change of Error

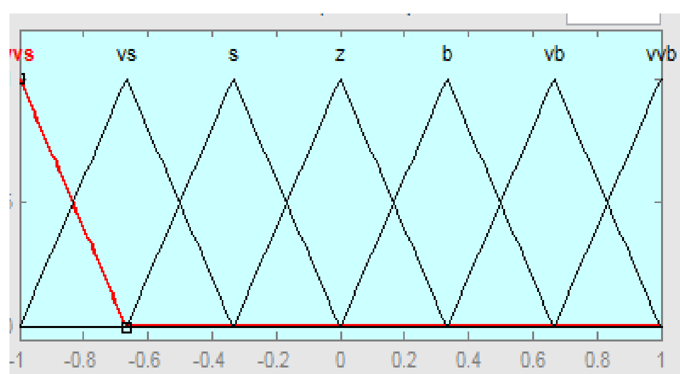

Fig. 5: Membership Function For Output

ISSN: 2349-6657 @ JSET

Table 2: Fuzzy Rule Base for Controller

Error / Derror	vvs	vs	s	z	b	vb	vvb
vvs	vvs	vvs	vvs	vvs	vs	s	z
vs	vvs	vvs	vvs	vs	s	z	b
s	vvs	vvs	vs	s	z	b	vb
z	vvs	vs	s	z	b	vb	vvb
b	vs	s	z	b	vb	vvb	vvb
vb	s	z	b	vb	vvb	vvb	vvb
vvb	z	b	vb	vvb	vvb	vvb	vvb

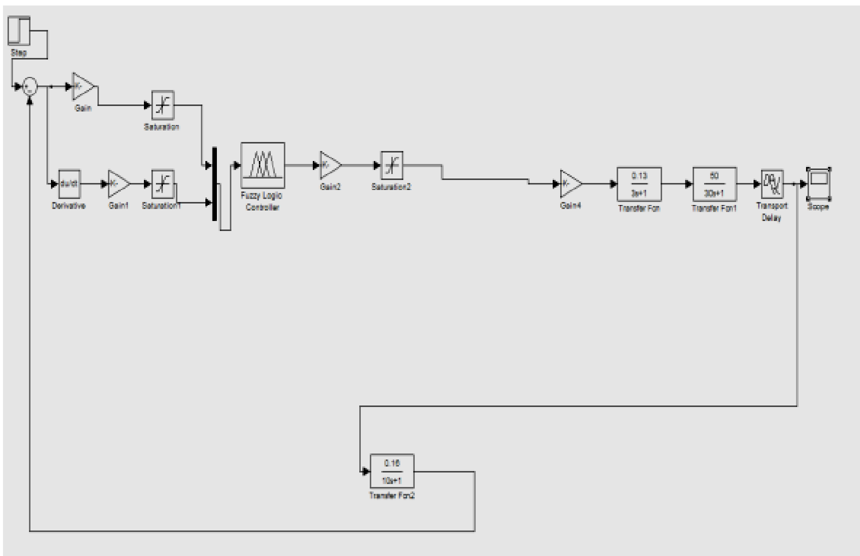

Fig. 6: Block Diagram of Fuzzy Logic Control of Heat Exchanger

V. Results

A unit step input is applied as set point and response is plotted for PI Control and Fuzzy Control is obtained. Rise time, Settling time and overshoot for the different controllers are obtained.

Table 3: Result Analysis

CONTROLLER	RISE TIME(s)	SETTLING TIME(s)	OVERSHOOT (%)
PI	80	1640	0
Fuzzy Logic	75	220	0

VI. Conclusion

Rise time, settling time reduces when Fuzzy Logic Controller is used for the process instead of PI Controller. Considerable lag is introduced in the process which gets reduced in the process. Rise time is comparable in both the cases

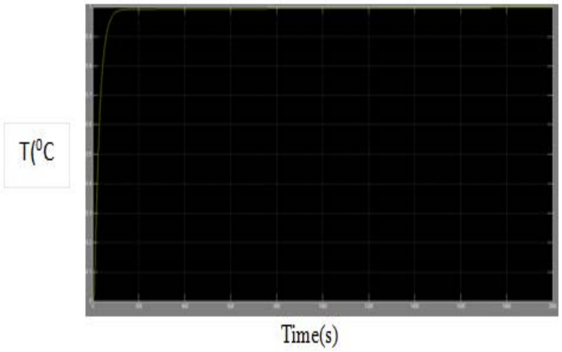

Fig. 7: Response for PI Control of Heat Exchanger

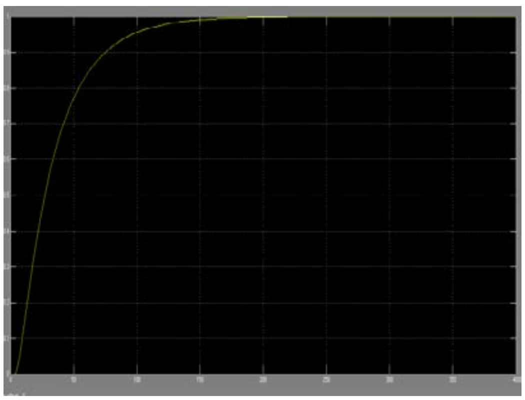

Fig. 8: Response for Fuzzy Logic Control of Heat Exchanger

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