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Fuzzy Logic Control of Heat Exchangers

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ABSTRACT

Heat exchanger are used in many process industries which transfer heat from one medium to another medium. This paper projects on design of Fuzzy Logic Controller and evaluation of response through time domain specifications. In this work Spiral, Plate and Shell and Tube heat exchangers are considered. Transfer function for Spiral, Plate and Shell and tube heat exchanger are obtained through system identification. Fuzzy Logic Controller is designed for Spiral, Plate and Shell and Tube heat exchanger and their simulation results are compared. The parameters such as rise time, settling time, Integral Absolute Error (IAE), Integral Square Error(ISE), Integral of Time and Absolute Error(ITAE) is calculated and compared to find the performance of Heat exchanger.

KEYWORDS: Fuzzy logic controller, Heat exchanger, System Identification.

INTRODUCTION

Heat exchanger is generally used in process industries, Nuclear plant, Palm oil process, Food, Mechanical system .Heat exchangers changes the temperature distribution of two fluids. In this paper Fuzzy Logic controller is designed for Shell and tube heat exchanger, Plate type heat exchanger and spiral type heat exchanger. Shell and Tube Heat Exchanger (STHE) consist of shell with bundle of tubes where one fluid flows through the tubes and another fluid flows through the shell to transfer heat between the two fluids. In Plate Heat Exchanger (PHE) the process of the heat transfer in two fluids with different temperature is done with surface contact. The output performance of heat exchanger is greatly influenced by plates. Plate arrangement has lower volume and cost when compared to shell and tube heat exchanger. Spiral Heat Exchangers is a modification to the perpendicular flow of the typical Helical-Coil Heat Exchanger (HCHE), it allows two fluids to flow parallel to one another and provide optimum heat transfer rate than shell and tube heat exchanger.

Controllers monitor and physically alters the operating conditions of a given dynamical system. Controllers are used in many process as it improve steady state accuracy by decreasing the steady state errors and increasing the stability of the system. They also help in reducing the offsets produced in the system. Controllers controls maximum overshoot of the system and also help in reducing the noise signals produced in the system. Fuzzy Logic Controller (FLC) has been successfully applied to a wide range of industrial processes. Fuzzy provide better results than PID controller which has no oscillation in the response. Fuzzy logic control is suitable to handle modelling difficulties, unreliable or precise instruments. It has advantages such as lesser computation time, user interface, consistency and redundancy can be checked in rule base.

II. Fuzzy Controller:

Fuzzy logic is easy to design which reduces the complexity of continuously varying systems. Fuzzy logic has the advantage that human operators can apply his knowledge and decision for the design of the controller. This makes it easier to do the tasks that are already successfully performed by humans. Fuzzy consist of an input ,a processing and an output stage. The input stage maps sensor or other inputs to the correct membership

functions and truth values. The processing stage involves appropriate rule and generates a result and then combines the results of the rules. Finally, the output stage converts the combined result into a definite output value. To attain the desired control objective and implement human intelligence in controller, a fuzzy logic controller is designed and implemented.

Fuzzy Logic Controller consist of Fuzzifier, Fuzzy rule base, Fuzzy knowledge base, Inference engine and a Defuzzifier. It also contain parameters for normalization.The Fuzzifier present converts the crisp quantities into fuzzy quantities. The fuzzy rule base stores the knowledge about the operation of the process.The fuzzy knowledge base stores the knowledge about all the input and output fuzzy relationships. It contain membership functions defining the input variables and output variables. The inference engine is the Kernel of a FLC and it provides capability to imitate human decision by performing approximate reasoning to achieve a desire control process.The Defuzzifier convert the fuzzy quantities into crisp quantities from an inferred fuzzy control action by the Inference engine.

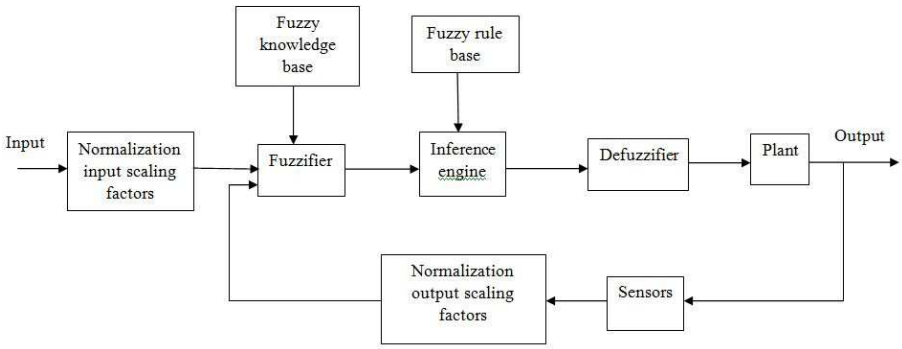

Fig. 1: General Block Diagram of Fuzzy Controller

Fuzzy Rule Base:

The Fuzzy logic controller converts the expert knowledge into an automatic control strategy. Fuzzy logic is capable of handling information in a systematic way and therefore it is suited for controlling non linear systems and used for modelling complex systems .The Fuzzy rule-based systems (FRBS) consist of set of fuzzy rules. Fuzzy allows the human intelligence to make decision about the problem by framing the rules .With an effective rule base, the Fuzzy control systems can replace a expert human operator. The rule base reflects the human expert knowledge and the membership functions represent interpretation of those variables.

The Fuzzy controller takes error 'e' and rate of change of error 'ec' as the input to the controller to modify the parameters. The rules designed are based on the characteristic of the Heat Exchanger. Mamdani model is applied to Fuzzy inference System.

e / ec	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PM	PM	PS	Z	Z
NM	PB	PB	PM	PS	PS	Z	NS
NS	PM	PM	PM	PS	Z	NS	NS
Z	PM	PM	PS	Z	NS	NM	NM
PS	PS	PS	Z	NS	NS	NM	NM
PM	PS	Z	NS	NM	NM	NM	NB
PB	Z	Z	NM	NM	NM	NB	NB

Fig. 2: Rules for Fuzzy Logic controller

The linguistic variable are assigned as

NB: Negative Big	PS: Positive Small	Z: Zero
NM: Negative Medium	PM: Positive Medium	
NS: Negative Small	PB: Positive Big	

Membership function:

The input error 'e' ,error change 'ec' and output membership function using triangular functions are shown in fig 3 and 4.

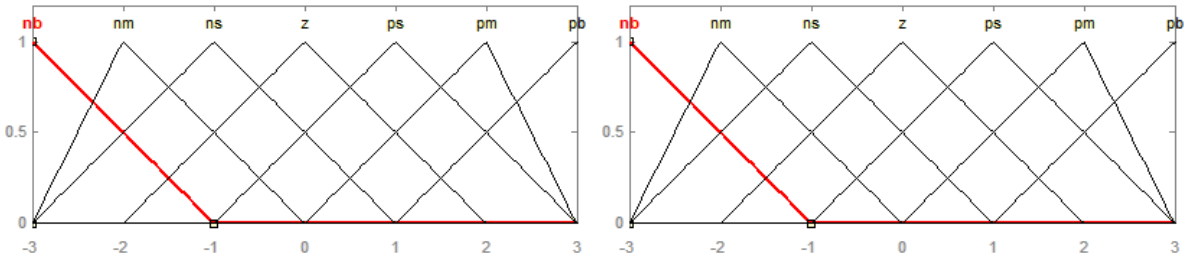

Fig. 3: Input membership function for e and ec

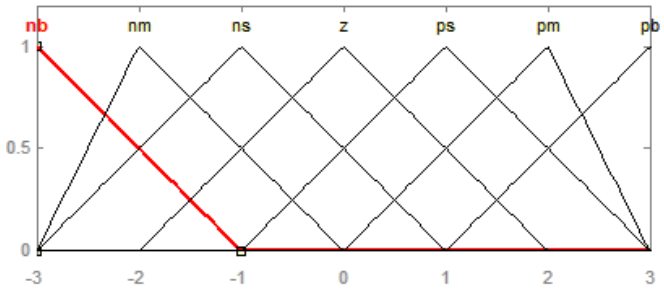

Fig. 4: Output membership function

IV. Spiral Type Heat Exchanger:

SHE are usually smaller than other types of heat exchangers. The advantage of the SHE is highly compact and high heat transfer rate than shell and tube heat exchanger. A compact SHE has lesser investment cost and have a lesser amount of pressure drop, a lesser amount of pumping energy, greater thermal efficiency. The transfer function of Spiral type Heat Exchanger is obtained through system identification toolbox using MATLAB. System identification is an experimental method to build model from input and output data. The model should be able to describe the behaviour of the process around an operating point. Transfer function of the spiral type heat exchanger obtained from system identification toolbox is G(S)= 0.61517/(1.731S+1)

V. Plate Type heat exchanger:

Plate Heat Exchangers consist of number of thin metal plates compressed together into a plate pack by two pressure plates. It has a high heat transfer rate when compared to other types of heat exchangers.The plates are made of Stainless steel, Copper, Titanium. Plate Heat Exchangers are small and efficient. It has high heat transfer rate because of its large surface area.The transfer function of plate type heat exchanger obtained through system identification toolbox using is G(S)=0.009975/(3S+1)

VI. Shell and tube Type heat exchanger:

A most common type of Heat Exchanger used in industries is Shell and Tube Heat Exchanger. This heat exchanger finds application in oil refineries and other huge chemical processes and is suitable for high pressure applications. It consists of a shell with a bundle of tubes inside it where one fluid runs through the tubes, and another fluid flows over the tubes to transfer heat between the two fluids. It has larger ratio of heat transfer surface to volume than double-pipe heat exchangers and it is easy to produce in a large range of size and arrangement. The Transfer function of Shell and Tube type heat exchanger is obtained through system identification toolbox is G(S)=3.959 /(4.546S+1).

RESULTS AND DISCUSSION

The performance analysis of shell and tube, spiral and plate type heat exchanger was observed using Fuzzy Logic controller which is shown in Fig 9.The evaluation parameters such as Rise Time, Settling Time, Integral Absolute Error (IAE), Integral Square Error (ISE) and Integral of Time and Absolute Error(ITAE) is calculated for the above heat exchangers and their comparative results are shown in T-1.From the simulation results we can infer that spiral type heat exchanger shows better response i.e. lesser rise and settling time than plate type and shell and tube heat exchanger. Integral absolute Error (IAE) integrates the absolute error over time and it tends to produce slower response. Integral Square Error (ISE)measure the system performance by integrating the

square of the system error over a fixed interval of time. Integral of Time and Absolute Error (ITAE) integrates the absolute error multiplied by the time over time. Shell and Tube heat exchanger has lesser IAE, ISE, and ITAE than other heat exchangers.

$$ISE = \int \varepsilon^2 dt$$

$$IAE = \int |\varepsilon| dt$$

$$ITAE = \int t|\varepsilon| dt$$

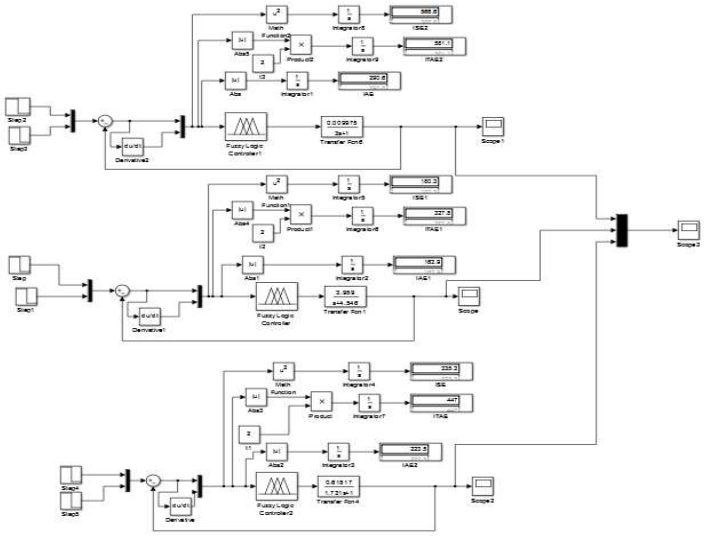

Fig. 5: Simulation block diagram for heat exchangers

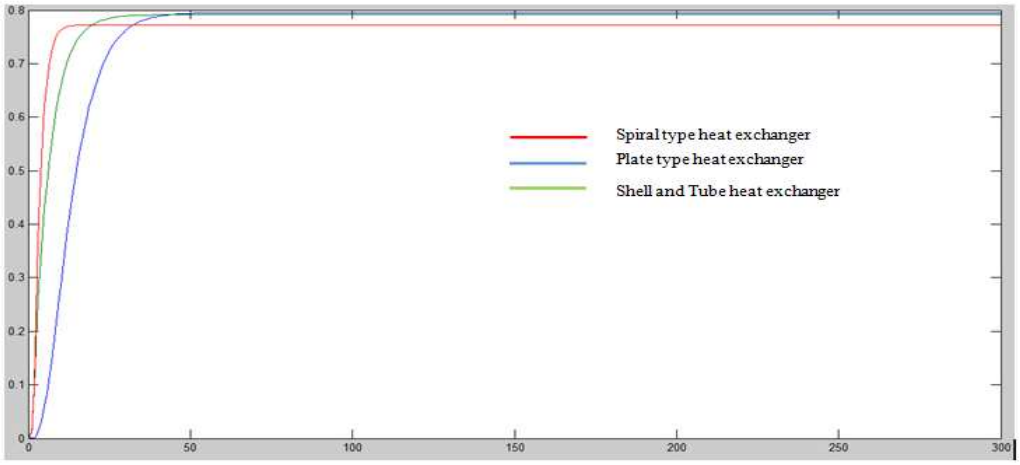

Fig. 6: Simulation results

T-1: Comparison of different parameters for Heat exchangers

Heat Exchanger	Rise time	Settling time	IAE	ISE	ITAE
Spiral	7	17	223.5	335.3	447
Plate	24.7	50	290.6	566.6	581.1
Shell and Tube	13.15	40	163.9	180.3	327.8

Conclusion:

Thus the response for Spiral, Plate Type, Shell and Tube heat exchanger using Fuzzy controller was observed.From which it is inferred that Spiral type heat exchanger shows better results than plate type and shell and tube heat exchanger. The parameters such as Rise Time, Settling Time, Integral Absolute Error (IAE), Integral Square Error (ISE) and Integral of Time and Absolute Error(ITAE)are calculated.

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