INDUSTRIAL APPLICATION OF FUZZY TIME CONTROL DISCRETE EVENT SYSTEM

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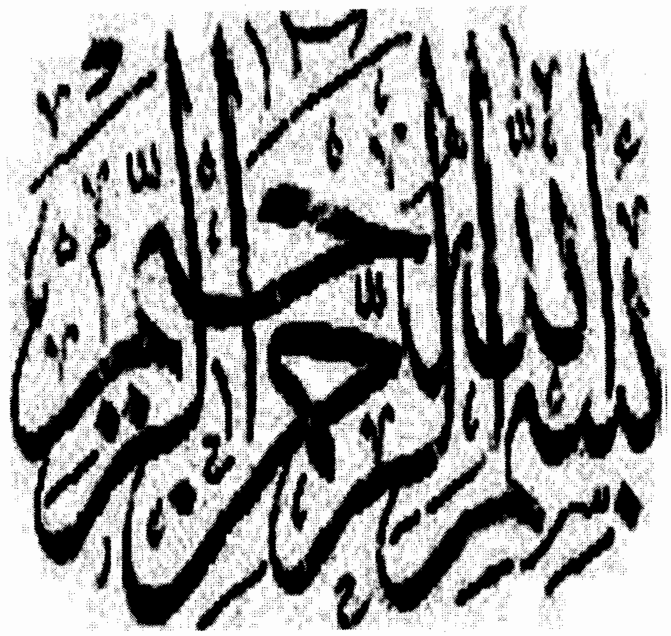
1. Intelligent control systems
2. Fuzzy systems



In The Name Of Allah The Most Beneficent The Most Merciful

DEDICATED

TO

Dedicated to My Affectionate **Father**, **Mother**, **Wife**, and Diligent **Teachers**, Who enabled me in making this humble contribution in scientific Knowledge.

ACKNOWLEDGEMENT

All praise to Almighty Allah the most beneficent the most merciful by the grace of whom I have been able to make this humble contribution to vast scientific knowledge. And the best regards to the benevolent Prophet Muhammad (P.B.U.H). Who has been a source of guidance throughout my life. I feel extremely fortunate to have worked under the supervision of professor **Muhammad Saleem Khan** (doctor of Philosophy in Physics) who always provided me with priceless support, suggestions and assistance. Furthermore it was my honor to work at International Islamic University Islamabad (IIUI).IIUI provided me with extremely encouraging and supportive environment for research and learning. Similarly I thank the Government college university Lahore to let me take benefit from their state of the art research material and equipment. Finally my special thanks and regards go to my parents who have been very supportive and compassionate not only during my work but throughout my life. My Allah give them happy healthy and life.

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PUBLICATIONS

1) SYED FAZIL BIN FARUKH AND M.SALEEM KHAN, "AUTONOMOUS AIR CONDITIONING SYSTEM",ICIIT-2010 IEEE.LAHORE, PAKISTAN.

2) SYED FAZIL BIN FARUKH AND M. SALEEM KHAN, "A NEW APPROACH OF SYRUP MANUFACTURINR USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM", ICCEE-2010 IEEE. CHENGDU, CHINA.

2) Syed Fazil Bin Farukh, M.Saleem khan," A NEW APPROACHOF SYRUP MANUFACTURING BY USING TIME CONTROL DISCRETE EVENT SYSTEM" Yanbu Journal of Engineering and Science (YJES).(EXTENDED PAPER)

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CHAPTER-1

INTRODUCTION

1.1 Overview of control system

Control system has got vital industrial applications in recent times. There are numerous applications of automation controls in nature and industry e.g. inside our body food digestive system, blood circulatory system, air plain autopilot, modern transportation, communication and in manufacturing industry. Automation provides better performance, reduces the manufacturing cost and provides mass production

Control system helps to identify and manage the parameters of the system/plant and provide desired system response. Generally a control system contains a controller to control the system, a plant or system which has to be controlled and an actuator to interface between the controller and plant.

1.1.1 BRANCHES OF CONTROL SYSTEM

Control system contains the following main branches: classical control, modern controls, optimal control, nonlinear controls, robust controls, adaptive controls and fuzzy controls.

(a) In Classical controls we study the performance of linear systems and their frequency analysis.

(b) Modern control studies the state space design and modeling of the system.

(c) Nonlinear control design techniques are used where nonlinear behavior of system has a dominant effect on performance of the system.

(d) Robust control techniques are applied for known bounded uncertainties of the system.

(e) Adaptive control techniques are applied to auto-tune the controller parameters when the system parameters are varying with time.

(f) Fuzzy control technique is based on human knowledge which is effectively used in the industrial automation.

1.1.2 CONTROL SYSTEM CONFIGURATION

Mainly control system classified in two configurations:

1) Open loop system.

2) Closed loop system [1].

(a) An open loop system is one which don't take any feedback it uses an actuator to directly control the plant .

(b) system which takes feedback and gives the difference between this feedback signal with input signal and than minimized that difference are called closed loop systems.

1.1.3 PROCESS / SYSTEM MODEL

A continuously acting control system to which the system act in response to the control action is called dynamical behaviour and a controller with these characteristics is known as dynamical control system.

Dynamical systems (D.S.) are mathematically designed. Which are based on physical laws. These (DS) are usually differential equations. In this research work design, modeling, simulation and industrial application of dynamical control system are discussed.

1.2 PROBLEM STATEMENT

Previously large number of classical controllers were designed for dynamical systems, using different techniques, some of these are: PID controller, adaptive controller, robust controller, optimal controller, which disuses their: observibility, controllability, stability and robustness and analyze them. These existing control models are rich with calculations and very difficult to deal with a complex system. It is desired to model dynamical control system with new approach for their industrial applications, such that they may reduce the complexity of the existing models and based on human knowledge.

To over come these problems "Fuzzy logic time control discrete event model" are designed. Using this approach soap manufacturing plant, ice-cream manufacturing plant, syrup manufacturing plant and autonomous air conditioning system are designed and verified using MATLAB simulation toolbox.

Numerous systems are designed using "fuzzy logic controls" (FLC) these systems are much better than conventional control system due to their simplicity in calculations and better performance. Fuzzy logic controls systems are based on heuristic knowledge, these systems takes numeric input and gives numeric output but the controller work on words. FLC are superior in their design and performance but did not take time into account. Time independency is their draw back.

It is desired to design a system which discusses the time control issues of the digital control system for which the output states make active the system, ON /OFF for limited interval of time.

The new designed autonomous air conditioning system, syrup manufacturing plant, soap manufacturing plant, and ice-cream manufacturing plant fulfill the local and distributive requirements. These systems are molded using new technique which is modified form of FLC. Fuzzy time control discrete event system is basically the grouping of two different systems. One is discrete system and other is fuzzy time system. which discusses the nonprobiblistic uncertainty issues [2]. This system contains a Fuzzifier, inference engine; rule of them, Defuzzifier, and discrete event system [3].

The work for autonomous air conditioning system designed using the technique of fuzzy time control discrete event system modifies and improves the existing air conditioning system model, designed model have the capability to auto adjust the air conditioning system according to the rule design for system and remove the function of remote control system due to its auto tuning which works by sensing the humidity and temperature of the environment. New designed model have the capability to replace the existing model. Due to its time dependency, designed system control the fan speed and fan spinning time by sensing the envoimental humidity and temperature and provides the conservation of energy due to its time dependency.

Same technique is used to design syrup manufacturing plant, ice-cream manufacturing plant, and soap manufacturing plant. In all of these three design models we provides the numeric value of input to them and in the response of these inputs we have to control the numbers of valves which controls the ingredients for the manufacturing of the desired item. These systems are much better in performance and have the flexibility to set the parameters of the systems according to the requirements of the manufacturing item and operate the plant for fixed interval of time.

1.3 FUZZY SYSTEM ENGINEERING.

Traditionally classical controllers work on two value logic judgment i.e. true-false or 0-1. There is no information between these two logic levels.

Fuzzy means between 0-1 (or) true –false. On opposed of conventional control approaches the fuzzy logic control system is independent of the long and complex mathematical modeling of the system. It works on the human reasoning and gives a proper methodology for implementation of heuristic knowledge to control a system [4]. Fuzzy logic controllers are design in such a way that they give the continuous value between 0 and 1.

Fuzzy control system has wide range of applications in engineering as well as in other field like medicine, physics, business etc [5].

1.3.1 FUZZY SET THEORY

Classical control system uses Boolean algebra which has two logic levels 0-1; fuzzy logic provides a way to work with continuous values between 0-1. In fuzzy control system, fuzzy sets are used which are basically the superset of Boolean algebra [4]. Elements of the fuzzy set have degree of membership functions. Fuzzy set explain the concept of physical systems which have no fixed discrete values such as old or very old, young or not very young. Fuzzy set A in universal set U contains elements which have their membership functions, the more the degree of membership function of an element the stronger the belongingness of that element to fuzzy set A [7-9].

1.4 FUZZY LOGIC TIME CONTROL DISCRETE EVENT SYSTEM

Fuzzy time control discrete event system is modified form of fuzzy (FLC); it is basically the combination of two different systems, fuzzy time control system and discrete event system. The proposed system work on heuristic knowledge deals with non probabilistic uncertainties [2], in which system takes the numeric inputs and gives numeric output but the controller work on words [10]. Numerous systems are designed using fuzzy logic control these systems are superior in their design and performance but are time independent. Time independency is their draw back. To overcome the time issues new technique is used to design the four systems. Which are time dependent and work for the fixed interval of time.

1.4.1 FUZZY LOGIC TIME CONTROL SYSTEM

Fuzzy logic time control system is sub divided into two parts; one is Generator (G), (which produce the numeric outputs) second is time control (TC), (TC produce the numeric value of time for output) [11]. Fuzzy time control system contains: Fuzzifiers, inference engine; rule of thumb with contains: data base, rule base and output membership functions [3], knowledge base is attached with the inference engine, defuzzifiers as exposed in the figure-1 numeric inputs are given to the Fuzzifier which converts these numeric inputs to linguistic variables, these linguistic variables are given to inference block where the max-min composition is applied to get four values of R. Knowledge base receives the crisp values and give singleton values according to the rules which are designed for model. These singleton values and values of R are provided to the defuzzifiers which converts the linguistic values to the numeric values here two defuzzifiers are used for a single input [3]. After defuzzification two numeric (crisp) values of outputs are obtained; one for output variable, other for output time. Analog to digital converter (ADC) used to alter the numeric value of output variable into binary code. Crisp value of output time is provided to the pulse strobe units, which allow the binary code to pass for a fix interval of time.

1.4.2 FUZZY DISCRETE EVENT SYSTEM

Discrete event system is further subdivided in to three parts; event control, process control and system control [12]. Event control takes input from fuzzy logic time control to generate and manage event. Process control takes inputs from system control and event control to assign a process for that event for a specific interval of time. System control controls the whole system for a specific interval of time. After defuzzification Binary control signals and time control signals from fuzzy logic time control system are given to discrete event system exposed in figure-1.1, which allow to pass these binary control signals to operate the plant ON or OFF for specific time period.

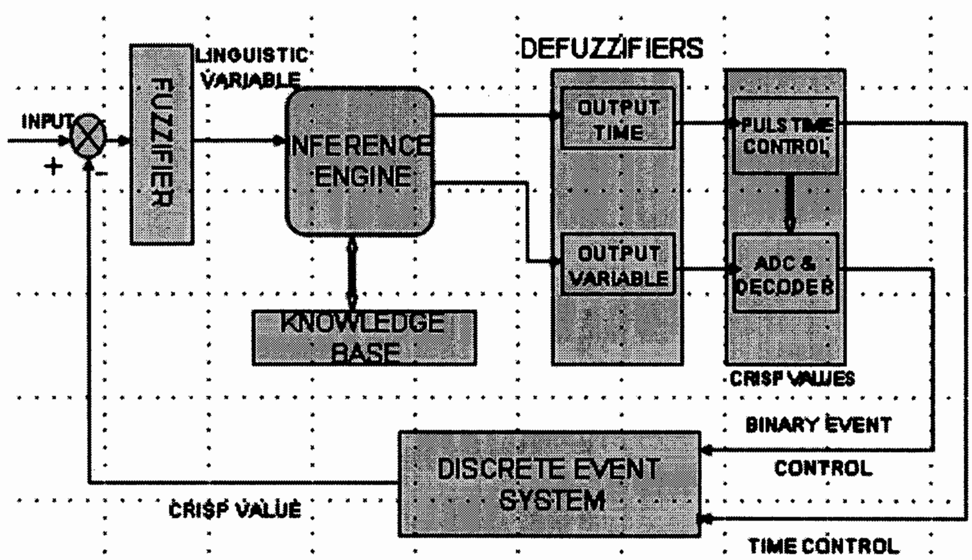


Figure-1.1 Fuzzy time control discrete event system

1.5 APPLICATIONS OF FUZZY LOGIC TIME CONTROL DISCRETE EVENT SYSTEM

Using fuzzy time control discrete event system four models; autonomous air conditioning system, syrup manufacturing plant, ice-cream manufacturing plant, and soap manufacturing plant are design as industrial applications.

1.5.1 AUTONOMOUS AIR CONDITIONING SYSTEM.

The autonomies air conditioning system is design for two inputs; temperature and humidity and two outputs; one is fan speed and the other is fan spinning time exposed in the figure-1.2

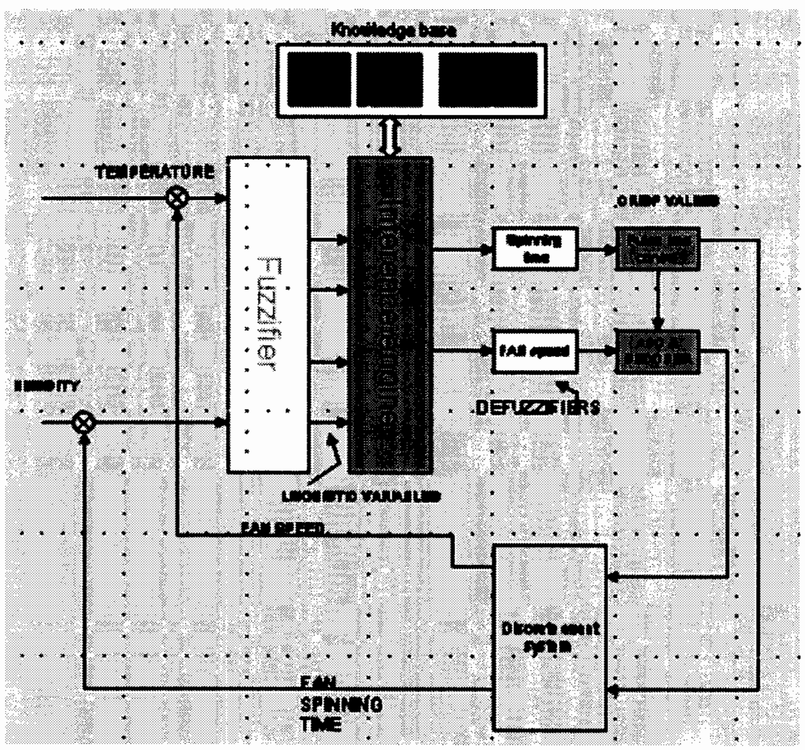


Figure-1.2 Fuzzy logic discrete event model

Numeric values of inputs; temperature and humidity are given to the Fuzzifier which converts numeric input to the linguistic variables these linguistic variables are then given to inference block where the max-min composition is applied to get four values of R. Knowledge base receives the crisp values and give four singleton values according to the rules which are designed for model. Knowledge base contains; date base, rule base, and output membership function [13]. These singleton values and values of R are provided to the defuzzifiers here two defuzzifiers are used, one for output fanspeed and fan spinning time. After defuzzification two numeric (crisp) values of outputs are obtained one for output variable; fan speed and other for fan spinning time. Analog to digital converter(ADC) is used to convert the crisp value of fan speed into binary code and crisp value of fan spinning time are provided to the pulse strobe unit , which allow to pass binary code for a certain time. Then these binary codes are used to make active discrete event system [14].

1.5.2 SYRUP MANUFACTURING PLANT USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM.

Pharmaceutical industries of world are manufacturing their most of the goods in syrup form. The proposed study relates with the designing of medicated syrup manufacturing using the fuzzy time control discrete event system. Syrup is the aqueous pharmaceutical preparation having the concentrated sugar solution with active and non-active ingredients. These preparations are manufactured by pharmaceutical industries following the standards of British and European pharmacopoeias in the whole world. The syrup solutions are characterized by parameters temperature, specific gravity, pH, and viscous consistency [15-18].

The system is designed with three inputs viscosity, specific gravity and chemical selection and eight outputs temperature, temperature time, mixing speed, mixing time, valve, valve opening time, PH at current liquid temperature, PH time System is controlled by controlling the four parameters valve selection, temperature monitoring unit, mixing motor, and PH control unit exposed in figure-1.3. System takes feed back from four sensors time control rules are formulated and simulated by using MATLAB tool box.

Three inputs; viscosity, specific gravity, and chemical selection are used for the designed syrup manufacturing system. Three numeric input values are given to three Fuzzifiers. After receiving numeric values of inputs these Fuzzifiers convert them into linguistic variables. These linguistic variables are then given to inference engine where the max-min composition is applied and gives eight values of R,s. Knowledge base provides eight singleton values according to the fuzzy rules designed for the proposed syrup manufacturing system after getting the crisp values. Defuzzifiers get eight values from inference engine and eight from knowledge base at its input and give the eight crisp values at its output. Here eight defuzzifiers are used for; temperature, mixing speed, PH, valve selection, temperature time, mixing time valve opening time, and PH time [7]. The values of four output variables are converted into binary codes using analog to digital converter (ADC) and decoder and crisp values of output time; temperature time, mixing time valve opening time, and PH time are provided to the pulse strobe units which provides the time pulses. These time pulses allow the binary codes to pass for a particular time. Then these binary codes are used to make active discrete event system under time constrain [8].

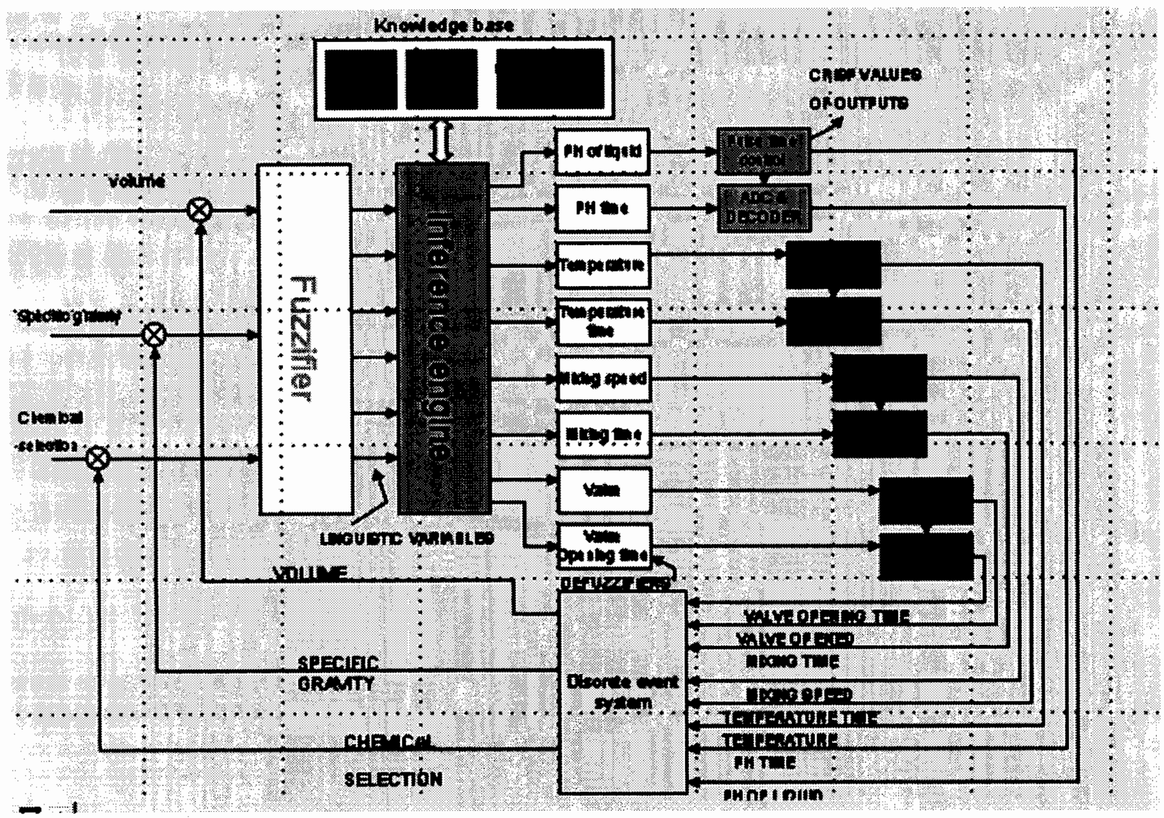


Figure-1.3 Syrup manufacturing fuzzy time control discrete event system.

1.5.3 ICE-CREAM MANUFACTURING USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM.

Ice cream is an important and very popular dairy product which is found in many flavors. With the development of the modern refrigeration system ice cream is manufactured is increased on large scale in industry [19-20]. The proposed Ice-cream manufacturing plant is designed to facilitate the ice cream manufacturing industry and provide a better and simple automated plant for manufacturing process which may reduce the complicity of the existing systems. Proposed ice cream manufacturing plant is designed using two inputs; volume, and ingredient selection and six outputs; heating/cooling temperature, temperature time, valve selection, valve opening time, mixing speed and mixing time exposed in figure-1.4. If the input (**u**) is given to the system and **(y)** be the output feedback value here an additional adjustment value **(a)** is added or subtracted to the system to minimize the error to get desired output value and quality control. So Fuzzifiers get input value **e**

$\underline{e} = u - y \pm a$

In case that the selected valve is not opened an additional parameter **b** is added or subtracted to the input; ingredient selection it cause to open other value, so the input value takes by the Fuzzifier is

$\underline{e} = u - y \pm b$

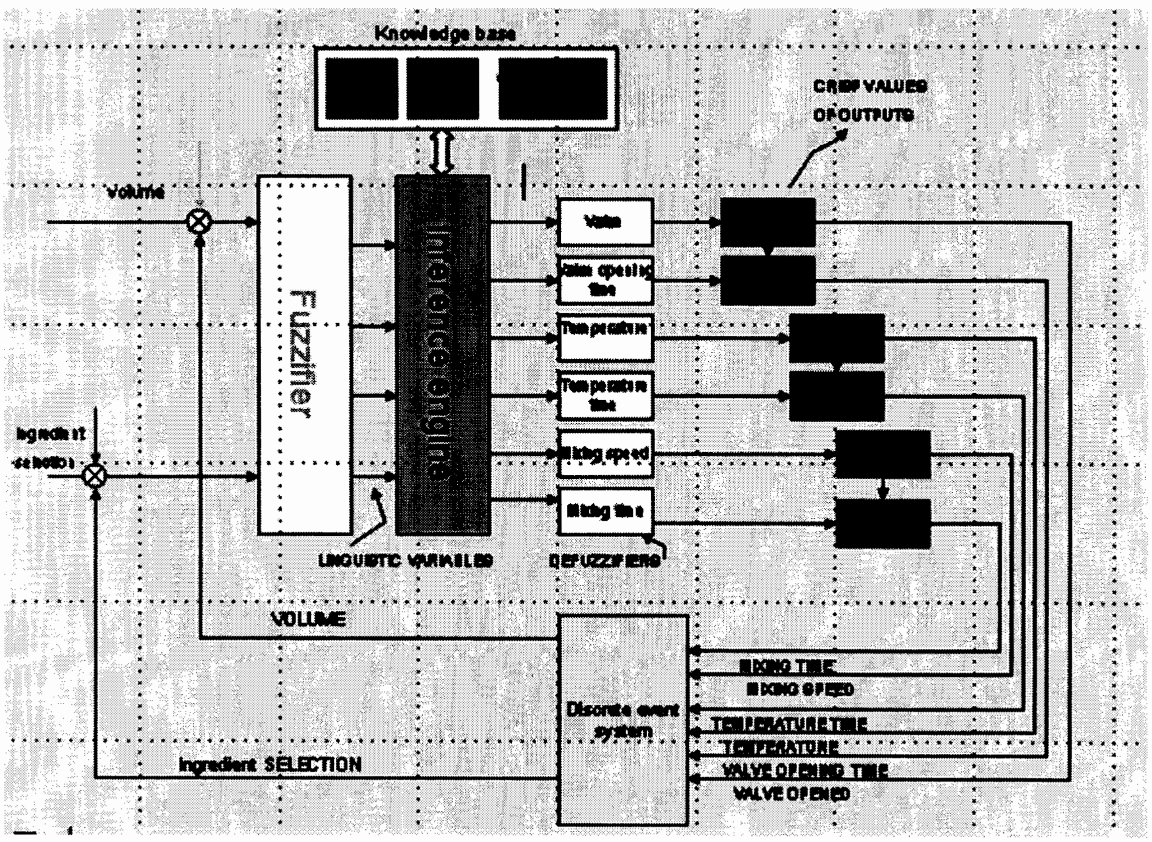


Figure-1.4 Design modeling of ice-cream manufacturing system.

1.5.4 SOAP MANUFACTURING USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM

Soap is an important anionic, disinfecting detergent which is frequently used in homes for bating, washing and many other ways in every day life due to their effective antibacterial property [21-22]. The efficacy of antibacterial property can be increased in these liquid soaps by doping the alcohol based hand sanitizers [23]. Soap comes in many different shapes and forms like liquid, powder and solid bar. The agricultural wastes which are thrown away in normal practice in under developed countries are used as raw material for the black soap. This agro-wastes ash based soap found to have excellent spectrum of solubility, cleansing and lathering abilities [24]. Aluminum soaps have the ability to form the high viscosity hydrocarbon gels [25]. The sodium laurate based soaps exhibits the high surface tension property [26]. The soap solutions are characterized by parameters temperature, specific gravity, pH, viscosity, volume and viscous consistency. The proposed soap manufacturing model is designed using fuzzy time control discrete event system in which four inputs; volume, viscosity, specific gravity and chemical selection and eight outputs; heating/cooling temperature, temperature time, valve selection, valve opening time, PH, PH time, mixing speed and mixing time are used exposed in figure-1.5.

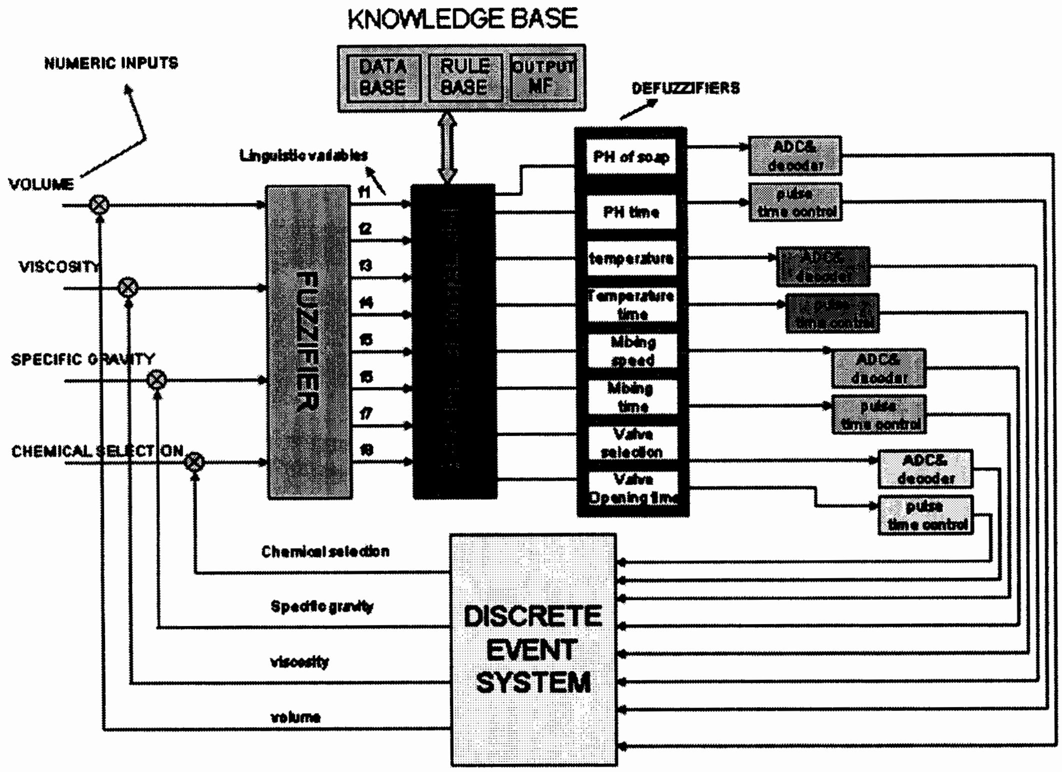


Figure-1.5 Design modeling of soap manufacturing system.

Four inputs; volume, viscosity, specific gravity, and chemical selection are used for the designed soap manufacturing system. Four numeric input values are given to the four Fuzzifiers. After receiving numeric values of inputs these Fuzzifiers convert them into linguistic variables. These linguistic variables are then given to inference engine where the max-min composition is applied and gives sixteen values of R,s. Knowledge base provides sixteen singleton values according to the fuzzy rules designed for the proposed soap manufacturing system after getting the crisp values. Defuzzifiers get sixteen values from inference engine and sixteen from knowledge base at its input and give the eight crisp values at its output. Here eight defuzzifiers are used for output; temperature, mixing speed, PH, valve selection, temperature time, mixing time valve opening time, and PH time [7]. The values of output are converted into binary codes using analog to digital converter (ADC) and decoder and crisp values of output time; temperature time, mixing time valve opening time, and PH time are provided to the pulse strobe units which provides the time pulses. These time pulses allow the binary codes to pass for particular time. Then these binary codes are used to make active discrete event system under time constrain [8].

1.6 SUMMARY

Control system is widely applied in the modern society and gives new and better automated systems. Fuzzy time control discrete event model is used to design, model and simulate the new systems for industrial applications.

In this research thesis following models are designed.

1) Designed, an autonomous air-conditioning system using fuzzy time control discrete event system.
2) Designed, a syrup manufacturing system for industrial applications using fuzzy time control discrete event system.
3) Designed, a new ice-cream manufacturing system for industrial applications using fuzzy time control discrete event system.
4) Designed, soap manufacturing model for industrial applications using fuzzy time control discrete event system.

1.7 DISSERTATION ORGANIZATION

This research work is completed in four chapters. Chapter-1 gives the introduction and overview of the control system engineering, design modeling and simulation of the dynamical control system, using new approach fuzzy time control discrete event system. This chapter also gives a brief comparison between conventional control system and fuzzy logic control system. Chapter-2 discuss the literature review and in chapter-3 we discuss the design modeling and experimental arrangements of the, Autonomous air conditioning system, syrup manufacturing system, ice-cream manufacturing system and soap manufacturing system. In Chapter-4 we discuss the MATLAB simulation results of the designed models and future work.

CHAPTER-2

LITERATURE REVIEW

Shakowat Zaman *et al.,* [27] presented the air conditioning system using the fuzzy logic control system; in their designed model they used two inputs and one out put in the input membership functions' plot they used five membership functions. Their designed system take feedback from sensors and controls the fan speed by sensing the envoi mental humidity and temperature.

Wang, L.-X. *et al.,* [28]described the generating method that generates fuzzy rules from numeric inputs the work is completed in five steps. At first the numeric input and output data is divided into fuzzy regions, in second step fuzzy rules are formed from these fuzzy regions, in third step assign the degree of membership functions to each rule, in fourth step combine rules are formed from generated rules and from human experts, in the last step defuzzified values are obtained from the mapping of these combined fuzzy rules.

Hoyer,R. *et al.,* [29] gave the brief review for the traffic controllers which are designed using fuzzy logic control. They improved and extend the idea for complex systems which is able to control the traffic flow from twelve different directions. Their fuzzy controller is designed with ten input variables and two output fuzzy variables and total seventy two fuzzy rules are designed for the proposed controller. System takes feedback from the sensors. The states of the traffic signals light are changed according to the density of the flow of traffic.

Cheung, J.Y.M. *et al.,* [30] designed a controller which controls the D.C. motor speed using fuzzy logic control system along with model reference adaptive control techniques. Model reference adaptive control plays the primary role to control the motor speed and fuzzy logic controller is used to control the adaptation gain. The fuzzy controller takes three inputs and converts these three numeric inputs to fuzzy linguistic variables which are then given to the inference engine to control the adaptation gain.

Popa,D. D. *et al.,* [31] presented the qualitative and quantitative study of the fuzzy logic control system and designed a controller to control D.C. motor speed to overcome the industrial problems. The designed model is tested at different speed ranges; they also gave the comparison between their designed fuzzy logic controller with PI controller by studying the controller performance, controller robustness, controller accuracy and controller stability. For the proposed controller total forty nine rules were designed, and triangular membership functions were used for the input and output variables.

Ghabri,M.-K. *et al.,* [32] presented the high speed discrete event system and used it to design hybrid Petri nets model using fuzzy logic controller. The proposed model of fuzzy controller used triangular membership functions for the input fuzzy variables and discrete fuzzy output fuzzy logic levels were obtained.

Lo Bello,L. *et al*., [33] discussed the traffic smoothing issues and designed a model using fuzzy optimization genetic algorithm. The designed fuzzy model for traffic smoothing contains two inputs and in each input three membership functions are used, nine fuzzy rules are designed for the proposed system. Genetic algorithm is used to tune the membership functions of the input fuzzy variables to get desired controller performance.

Khan, M. S., [2] presented the grinding and mixing system which was designed using the fuzzy time control discrete event system. The proposed system contained four input variables and eight output variables, out of these eight outputs four were fuzzy variables and four are for output time. The designed system was fully time control and due to discrete event system controller used to operate the plant for a specific period of time.

Homaifar *et al.,* [34] presented the simultaneous design of membership functions using genetic algorithm. And tested the designed method by designing a cart controller and truck controller. Fuzzy if-then rules are used in the fuzzy controller and optimization problems were overcame using fuzzy genetic algorithm.

Chang Jian *et al.*, [35] presented a new hardware design to set up fuzzy logic controller and encounter the problems in L.A. Zadah fuzzy logic method by adding some new characters to fuzzy sets and fuzzy rules. They also designed a fuzzy temperature control system and improve the speed and scale of the fuzzy control system.

Bin-Da Liu *et al.*, [36] developed a tree-based approach for fuzzy logic control system and applied this approach to color reproduction system. In the designed tree-based fuzzy logic controller the input and output data can be used to take out rules in one phase, they reduced the fuzzy inference process by reducing the n-dimensional matrix to one-dimensional matrix.

Solano S. S. *et al.,* [37] presented the design of digital fuzzy controllers and their hardware implementations. They described the structure and functions of the input fuzzy set, inference mechanism and defuzzifiers. They also designed two integrated circuits of the controllers using their ideas.

Kim J. H. *et al.,* [38] presented the multi type air conditioner using fuzzy logic control techniques. In the designed algorithm the fuzzy controller is used to operate the linear expansion valve. The proposed fuzzy controller was designed using seven membership functions for both input and output fuzzy variables, forty nine fuzzy rules were designed for the controller and center of gravity method was used for defuzzification.

Jyh Shing Roger Jang *et al.,* [39] proposed adaptive-network-based fuzzy inference system and gave their modeling and applications. They explained the fuzzy reasoning for rules and gave a brief review of fuzzy models, explained their designing and performance.

Thomas Hollstein *et al.*, [40] presented the computer aided design for fuzzy systems and proved that the fuzzy systems implementation in hardware gives better performance as compare to the software implementations on microcontrollers. They designed the hardware structure of fuzzy controllers and gave two computer aided design for hardware combination of two fuzzy controllers.

CHAPTER-3

DESIGN MODELING AND EXPERIMENTAL ARRANGEMENT.

3: INTRODUCTION.

In chapter-3 we present the design, modeling and experimental setup of autonomous air conditioning system, syrup manufacturing plant, ice-cream manufacturing plant, and soap manufacturing system. All these models are designed using fuzzy time control discrete event system.

3.1 DESIGN OF AUTONOMOUS AIR CONDITIONING SYSTEM.

Nowadays, the trend is to make systems, which use less energy, and give maximum efficiency. The proposed autonomous air conditioning system is designed to fulfill these conditions and provides the conservation of energy due to its time dependency.

3.1.1. DESIGN ALGORITHM.

The autonomies air conditioning system is designed for two inputs; temperature, humidity and two outputs; one is fan speed and the other is fan spinning time. We have to control the fan speed by sensing the input parameters according to the environmental conditions under time constrain. The membership functions and ranges of input variables are specified in the table-3.1, and table-3.2.

Table-3.1 Input membership function for temperature and their ranges

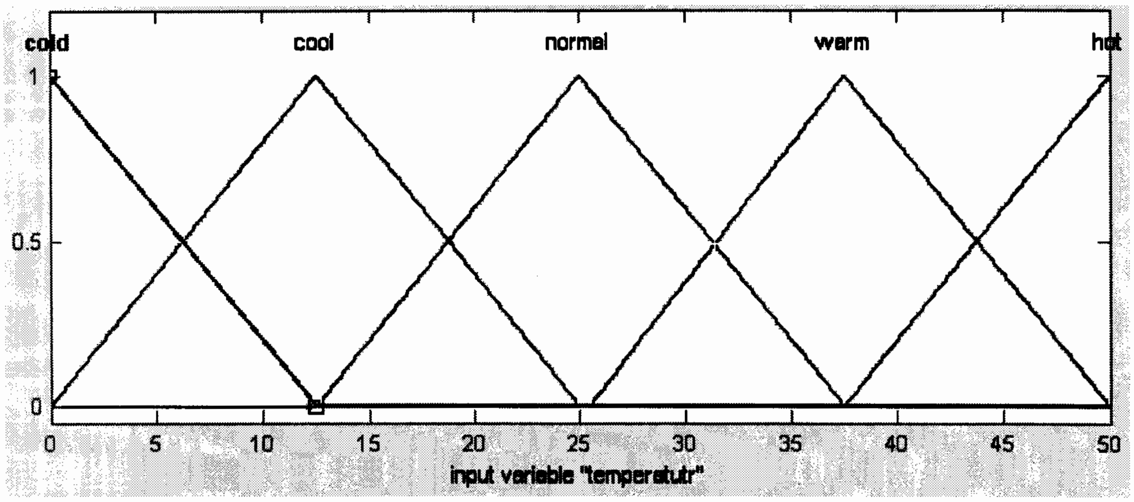
No	Membership function(MF)	Temperature(C)
1	Cold	0—12.5
2	Cool	0—25
3	Normal	12.5—37.5
4	Warm	25—50
5	Hot	37.5—50

Table-3.2 specified the input membership functions and ranges of humidity for the proposed autonomous air conditioning system.

Table-3.2 Input membership function for humidity, their ranges

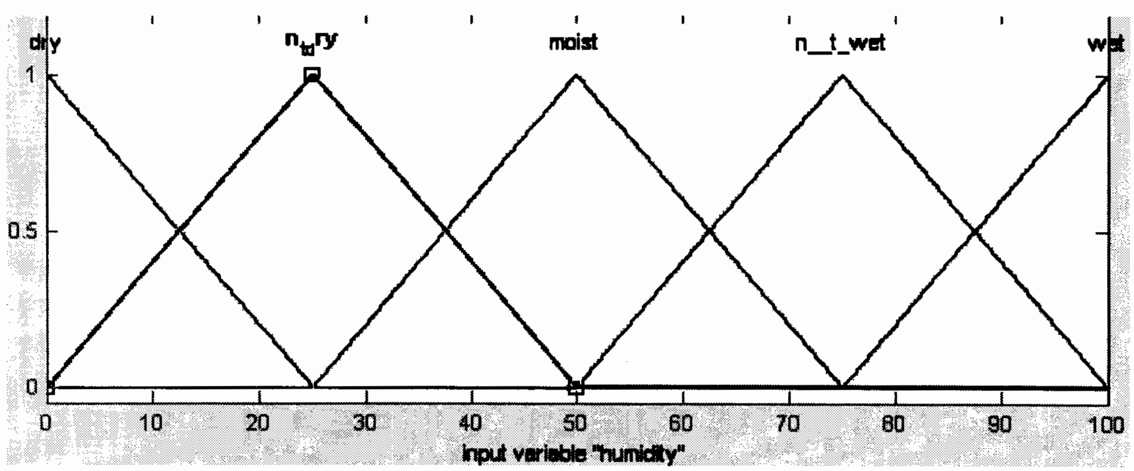
No	Membership function(MF)	Humidity
1	DRY	0%—25%
2	JUST DRY	0%—50%
3	MOIST	25%—75%
4	JUST WET	50%—100%
5	WET	75%—100%

The plot of input membership function of temperature exposed in figure-3.1 there are five membership functions i.e. F_1 [1], F_1 [2], F_1 [3], F_1 [4], F_1 [5] and four regions.



Figure—3.1 Membership function plot for temperature

Plot of membership functions for humidity exposed in figure-3.2 there are five membership functions i.e. $F_2[1]$, $F_2[2]$, $F_2[3]$, $F_2[4]$, and $F_2[5]$ and four regions.



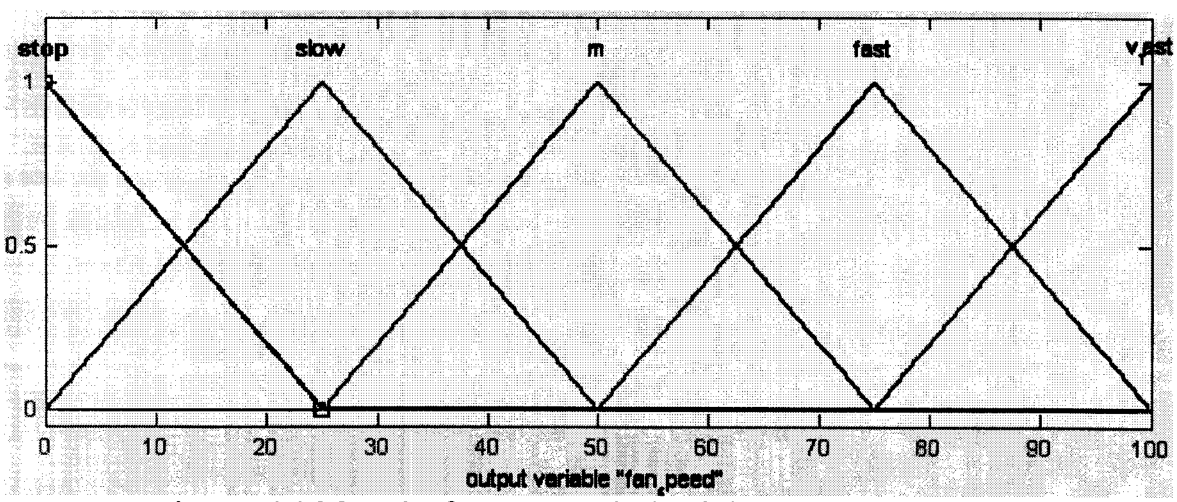
Figure—3.2 Membership function plot for humidity

The membership functions and ranges of two outputs are listed in the table-3.3. For the convenience in calculation the range values of output membership functions for fan speed and fan spinning time are taken same.

Table-3.3 Output membership function ranges for fan speed and fan spinning time

Membership Functions	Range	Fan speed	Fan spinning Time.
MF1	0-25	STOP	NONE
MF2	0-50	SLOW	SMALL
MF3	25-75	MEDIUM	MEDIUM
MF4	50-100	FAST	LONG
MF5	75-100	V-FAST	VERY LONG

Plot of output membership functions exposed in figure-3.3, each plot of output MF,s for fan speed and fan spinning time contain five MF,s and four regions.



Figure—3.3 M.F. plot for output variable of air conditioning system.

3.1.2 FUZZIFICATION.

First step in the designed model is the fuzzification in which numeric inputs are given to the fuzzifier which converts these numeric inputs to the linguistic variables. The design model of autonomous air conditioning system contains two inputs: temperature and humidity. Membership functions plot contain five regions for each input variable and these input: temperature and humidity maps to MF, s which may lie in any of the five regions as exposed in input plot. Here f_1 and f_2 are taken as the linguistic values of input temperature and f_3 and f_4 as linguistic values of input variable humidity.

The mapping combinations of input temperature and humidity to all the five regions are exposed in table-3.4

Table-3.4 All possible outputs of fuzzifier for the design model.

Input variable	Fuzzifier Output	Region-1	Region-2	Region-3	Region-4	Region-5
Temperature	f_1	$F_1[1]$	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$
	f_2	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$	$F_1[6]$
Humidity	f_3	$F_2[1]$	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$
	f_4	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$	$F_2[6]$

For the design model of air conditioning system we use two inputs so the fuzzifier gives four outputs exposed in the figure-3.4

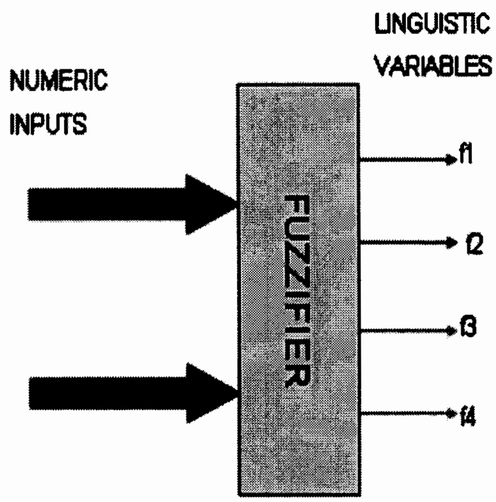


Figure-3.4 Design of fuzzifier for autonomous air conditioning model.

In this design algorithm we use two inputs so for these two inputs, two different fuzzifiers are used. The linguistic output of fuzzifier may lie in any of the five regions and each region is divided in to two halves; 1st half region and 2nd half region. Possible outputs of fuzzifier relation with these regions specified in table-3.5

Table-3.5 Fuzzifier relation of linguistic output values for air conditioning system.

Input	Fuzzifier Output	1st half region	2nd half region	Mid point region	Starting region
Temperature	f_1 f_2	$f_1 > f_2$	$f_1 < f_2$	$f_1 = f_2$	$f_1 = 1$ $f_2 = 0$
Humidity	f_3 f_4	$f_3 > f_4$	$f_3 < f_4$	$f_3 = f_4$	$f_3 = 1$ $f_4 = 0$

To verify the design model of the autonomous air conditioning system use the input fuzzy variable temperature=22°c and humidity=30 this value of temperature exist in the second part of second region and this value of the humidity exist in the first part of the second region. Where the given value 22 of temperature maps with the MF cool and normal for which the normal is taken as F [1] and cool is taken as F [2] similarly the value 30 of humidity maps with the value MF moist and just dry for which the moist is taken as F [3] and just dry is taken as F [4].

The fuzzifier results for this proposed algorithm exposed in the table-3.6

Table—3.6 Fuzzifier results for air conditioning model

Input variable	Value	Region selection	Fuzzy set calculation
Temperature	22	Region 2	F[1]=0.24 F[2]=1-F[1] =0.76
Humidity	30	Region 2	F[3]=0.2 F[4]=1-F[3] =0.8

3.13 INFERENCE ENGINE

Inference engine takes four inputs from fuzzification apply the min-and operation and gives the four values i.e. R_1, R_2, R_3 and R_4 exposed in the figure-3.5.

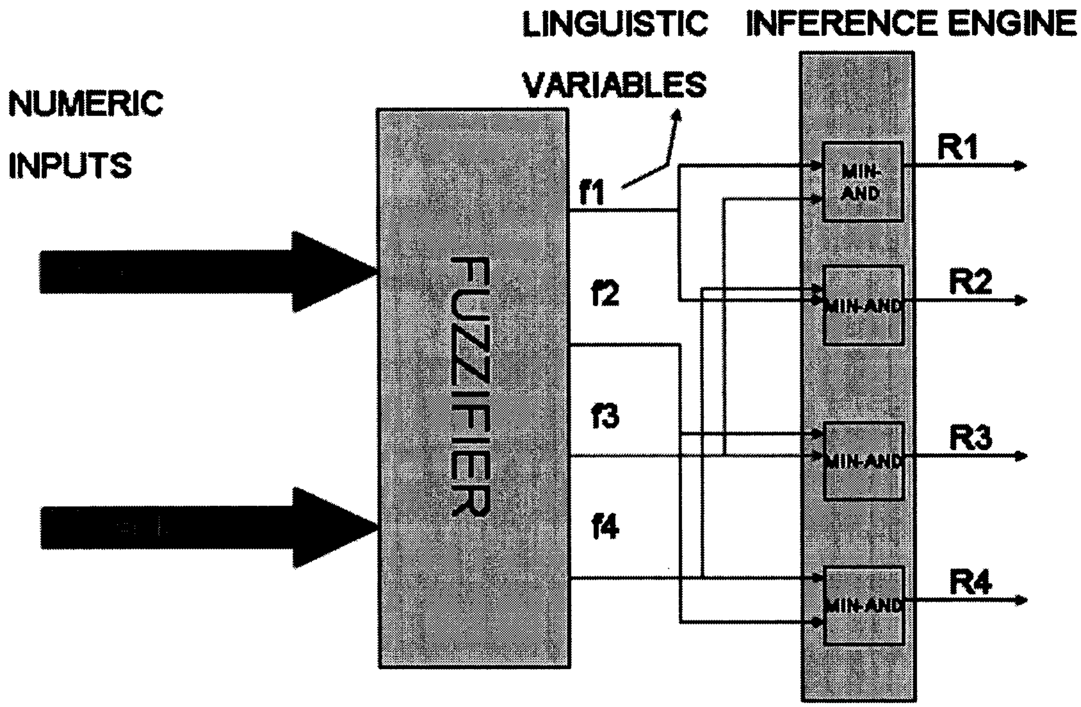


Figure-3.5 Inference engine design for air conditioning model.

In the output membership function plot there are five overlapping regions; system is designed with two inputs so total twenty five rules are applied for this proposed system [41]. But for each value of input variables i.e. for temperature=22, humidity=30 four rules are fired at a time at these values of input variables, rule no 7, 8, 13, 12 are used as shown in table-3.8 out of total twenty five rules

Inference engine takes four input values from the fuzzifier and applies max-min composition and give values of R. in this case four min-AND operations are applied to get the four values of R.

R_1=F [1] and F [3] = 0.24 and 0.2 = 0.2

R_2=F [1] and F [4] = 0.24 and 0.8 = 0.24

R_3=F [2] and F [3] =0.76 and 0.2 = 0.2

R_4=F [2] and F [4] = 0.76 and 0.8 = 0.76

3.1.4 RULE SELECTOR

The rule base takes the two numeric values of inputs; temperature and humidity and gives the four singleton values by applying the if-then rules [42], are exposed in figurer-3.6.

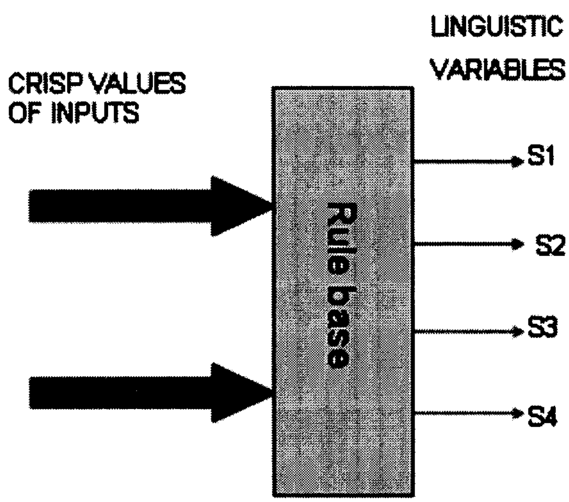


Figure-3.6 Design model of input and output of rule base for air conditioning system.

In the output membership functions plot there five overlapping regions and two inputs are used for system so total twenty five rules are required, these twenty-five rules exposed in table-3.7

Table—3.7 Rules designed for system

NO	Temperature	Humidity	Fan speed	Fan spinning time
1	Cold	Dry	Stop	None
2	Clod	Just dry	Stop	None
3	Cold	Moist	Stop	None
4	Cold	Just wet	Stop	None
5	Cold	Wet	Slow	Small
6	Cool	Dry	Stop	None
7	Cool	Just dry	Stop	None
8	Cool	Moist	Stop	None
9	Cool	Just wet	Slow	Small
10	Cool	Wet	Slow	Small
11	Normal	Dry	Slow	Small
12	Normal	Just dry	Slow	Small
13	Normal	Moist	Medium	Medium
14	Normal	Just wet	Medium	Medium
15	Normal	Wet	Fast	Long
16	Warm	Dry	Medium	Long
17	Warm	Just dry	Fast	Long
18	Warm	Moist	Fast	Long
19	Warm	Just wet	Fast	Long
20	Warm	Wet	Very fast	Long
21	Hot	Dry	Fast	Long
22	Hot	Just dry	Very fast	Very long
23	Hot	Moist	Very fast	Very long
24	Hot	Just wet	Very fast	Very long
25	Hot	Wet	Very fast	Very long

For this proposed system of air conditioning system out of these twenty-five rules, only four rules are selected at a time for single value of each input.

For temperature=22^{0}c and humidity=30 % the four rules selected out of twenty-five rules exposed in the table—3.8

Table-3.8 Selected rules for input variables

Rule No.	Temperature	Humidity	Fan speed	Fan spinning time
7	Cool	Just dry	Stop	None
8	Cool	Moist	Stop	None
12	Normal	Just dry	Slow	Small
13	Normal	Moist	Medium	Medium

Corresponding to these four rules four singleton values; S1, S2, S3, and S4 are obtained which exposed in the table-3.9.

Table—3.9 Singleton values for outputs

Singleton value	Fan speed	Fan spinning time
S_1	0	0
S_2	0	0
S_3	0.25	0.25
S_4	0.5	0.5

Rule base block for the designed model of air conditioning system contains lookup table, it consists of rules which are design for modeled. Two comparators, two detectors and two decoders , these detectors and decoders tell about the region maps by the input variable and response of fuzzy set to these variable. Comparator takes information's from detectors and decoders and gives the singleton values, as exposed in the figure-3.7.

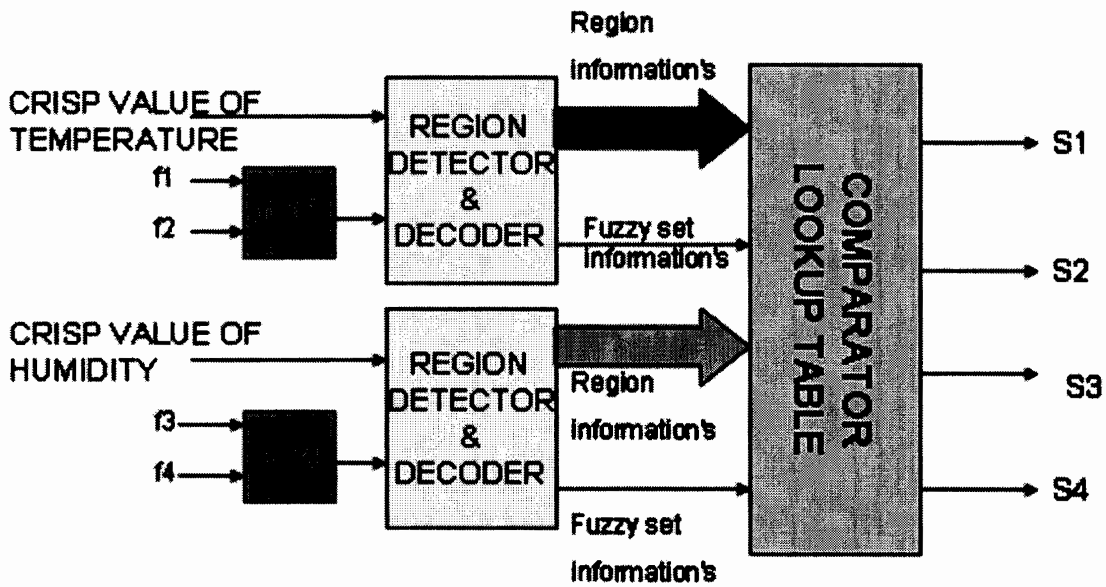


Figure-3.7 Arrangement of rule base to get singleton values for air conditioning system.

3.1.5 DEFUZZIFICATION.

The conversion of linguistic variables in to crisp/numeric values is done by using defuzzification. Many methods are used for this purpose of defuzzification e.g. (MOM) mean of maximum. (SOM) smallest of maximum (LOM) left of maximum etc.

The method used for defuzzification is (COA) center of average

Whose mathematical form is:

$$\sum_i Si * Ri / \sum Ri$$

Where i =1, 2, 3, 4

For the designed air conditioning system two defuzzifiers are used, one for output variable fan speed and other for fan spinning time. This system takes eight inputs to each defuzzifiers four from inference engine i.e. R_1, R_2, R_3 and R_4 and four from the rule base i.e. S_1, S_2, S_3 and S_4 and gives the crisp value of output fan speed and fan spinning time. As exposed in the figure-3.8.

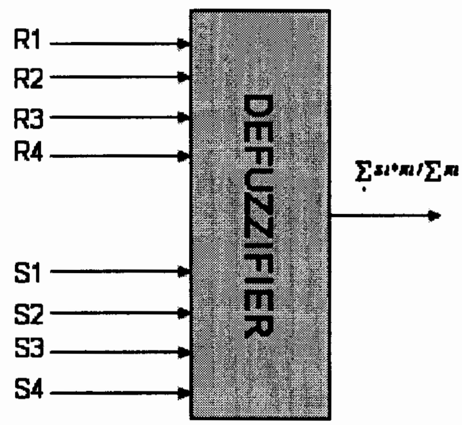


Figure-3.8 Block diagram of defuzzifier for air conditioning system.

The modeling of defuzzifier is shown in the figure-3.9; one defuzzifier contains adder, multipliers and divider. For the air conditioning system we require four multiplies, two adders and one divider to implement the COA method.

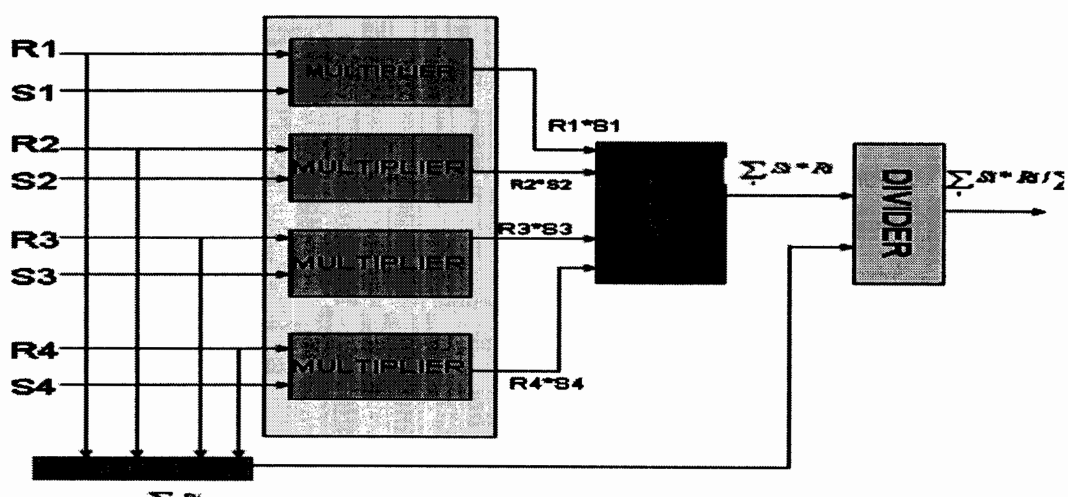


Figure-3.9 Modeling of defuzzifier for air conditioning system

3.1.6 EXPERIMENTAL ARRANGEMENT.

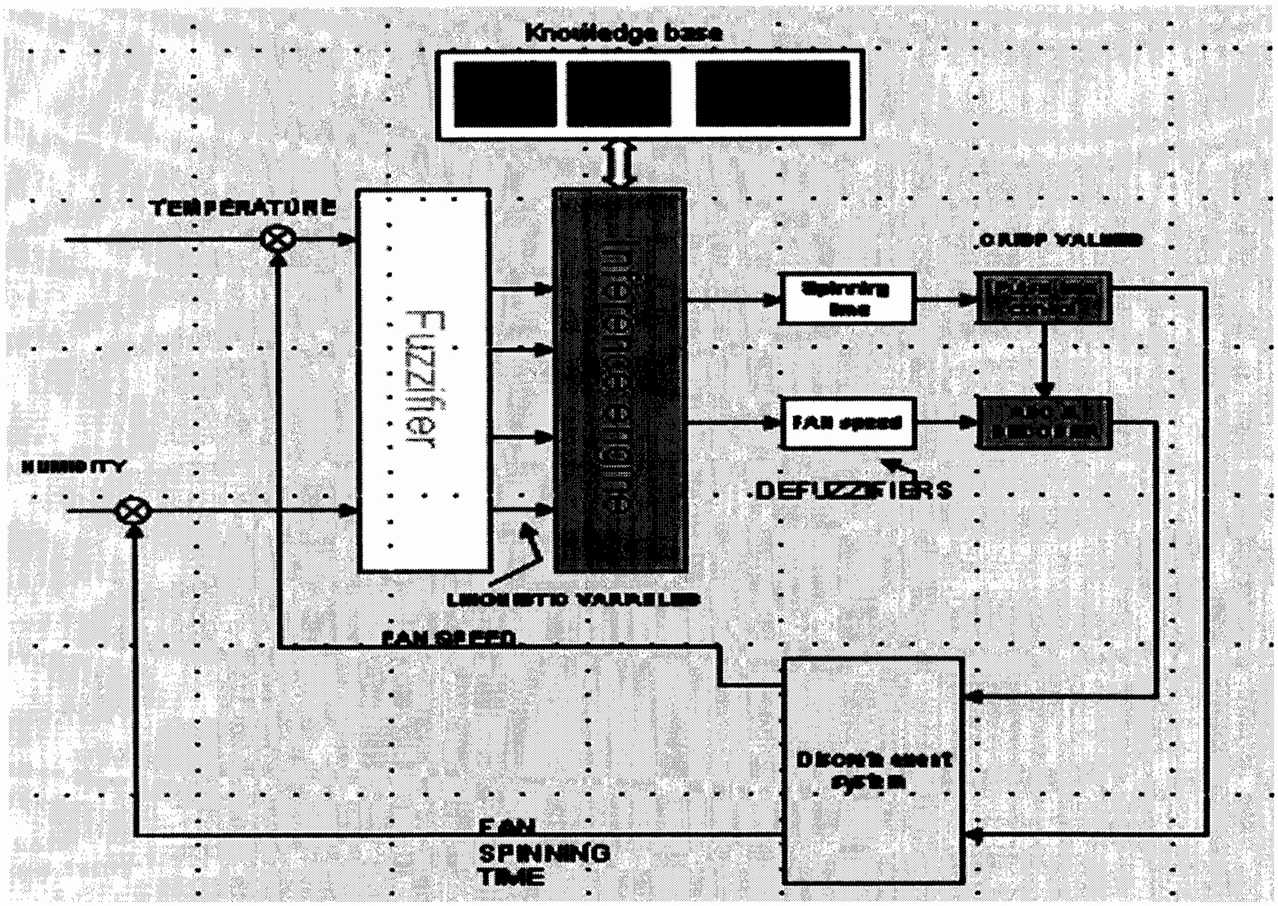


Figure-3.10 Experimental arrangement for air conditioning system.

3.2 DESIGN AND MODELING OF SYRUP MANUFACTURING SYSTEM USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM.

Pharmaceutical industries of world are manufacturing their most of the goods in syrup form. The proposed study relates with the designing of medicated syrup manufacturing using the fuzzy time control discrete event system.

3.2.1. DESIGN ALGORITHM.

The syrup manufacturing system is designed with three inputs; viscosity, specific gravity and chemical selection and eight outputs; temperature, temperature time, valve selection, valve opening time, PH at current liquid temperature, PH time, mixing speed, mixing time, each input plot contains six membership functions and five regions the name of membership functions and their ranges exposed in the table-3.10.

Table-3.10 input MF and their range values.

NO	Membership Function	Viscosity dyn.s/cm²	Specific Gravity Mg/ml	Chemical selection
1	Very small	0-1	0-1	0-10
2	Small	0-2	0-2	0-20
3	Medium	1-3	1-3	10-30
4	Above medium	2-4	2-4	20-40
5	High	3-5	3-5	30-50
6	Very high	4-5	4-5	40-50

In response of chemical selection valve are opened, installed at the feed lines for material constituents flow.

Plot of input membership functions (MF) for specific gravity exposed in the figure-3.11 there are six MF,s $F_1[1]$, $F_1[2]$, $F_1[3]$, $F_1[4]$, $F_1[5]$, and $F_1[6]$ and five regions.

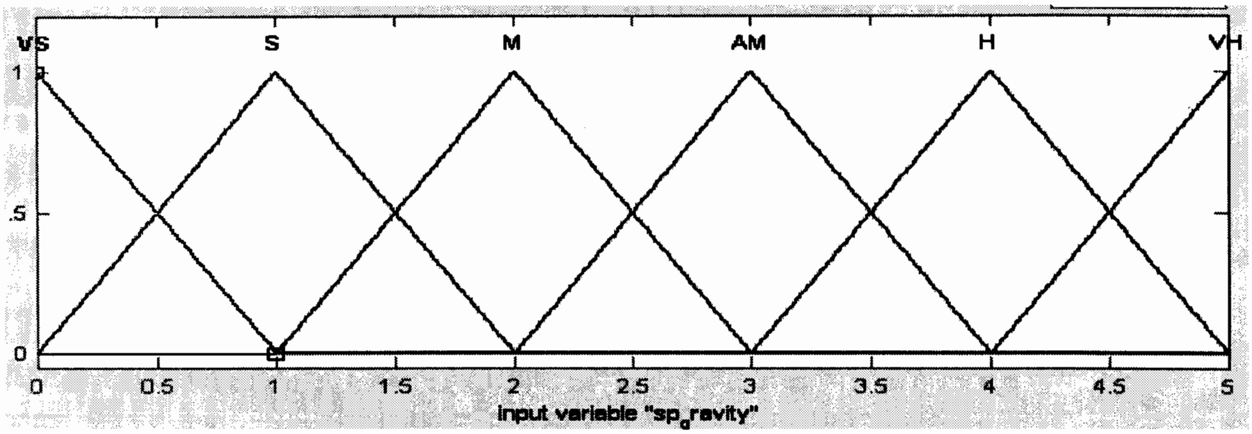


Figure-3.11 Input MF function specific gravity plot

Plot of input MF,s viscosity contains six MF, s and five regions input numeric value of viscosity exist in the one of the existing five regions exposed in the figure-3.12.

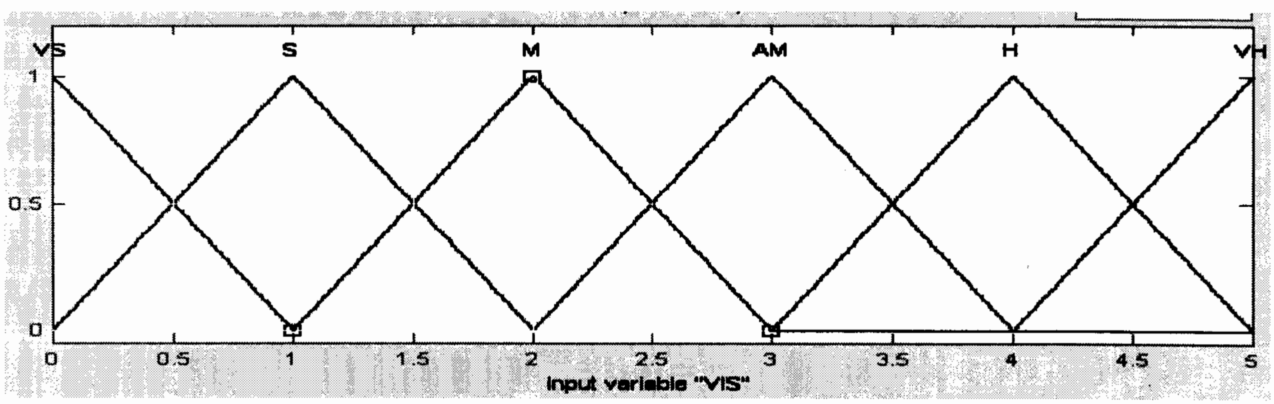


Figure-3.12 Input MF plot for viscosity

Plot of input MF chemical selection contains six MF,s $F_3[1]$ $F_3[2]$, $F_3[3]$, $F_3[4]$, $F_3[5]$, $F_3[6]$ and five regions exposed in the figure-3.13.

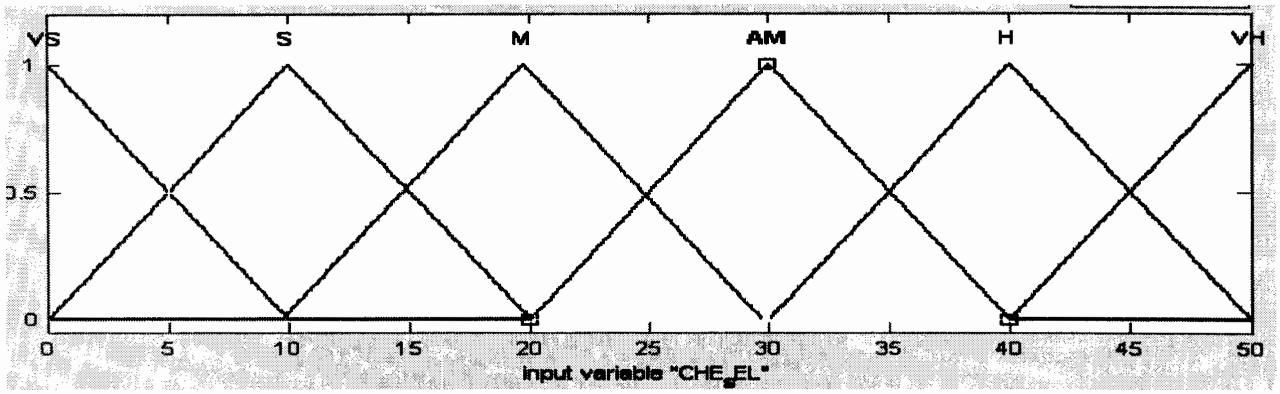


Figure-3.13 Input MF plot of chemical selection.

Plot of output MF,s are exposed in the figure-3.14 for the convenience in calculation the range values for the output MF,s for mixing speed, mixing time, valve selection, valve opening time, PH at given temperature, PH time, Temperature, Temperature time are taken same, plot contains five output MF, s and four regions

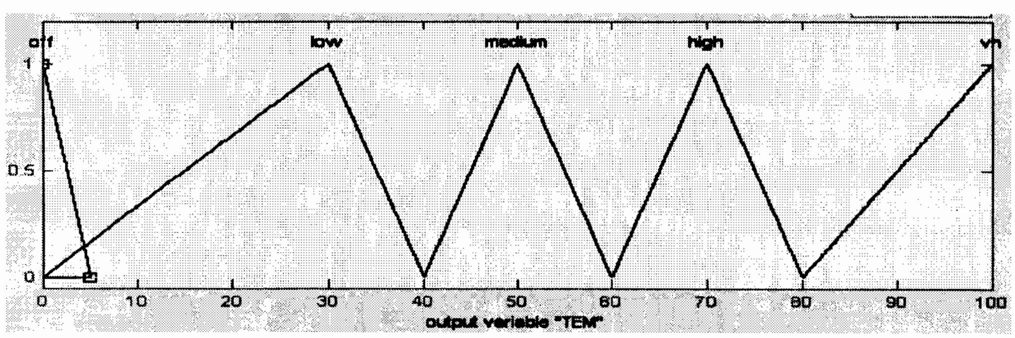


Figure-3.14 Output MF plot

The membership functions and ranges of eight output variables are presented in thetable-3.11.

Table-3.11 Output MF,s and their ranges.

Membership Function	Range	Temperature	Temperature Time	PH	PH time	value	Valve Opening time	Mixing speed	Mixing Time
MF1	0-5	Off	None	Small	None	None	None	Stop	None
MF2	0-40	Low	Small	Normal	Small	Few	Small	Slow	Small
MF3	40-60	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
MF4	60-80	High	Long	High	Long	Large	Long	Fast	Long
MF5	80-100	Very-high	Very-long	Very High	Very-long	Very large	Very-long	Very fast	Very-long

3.2.2 FUZZIFICATION.

First step in the design model is the fuzzification in which numeric inputs are given to the fuzzifier which converts these numeric inputs to the linguistic variables. The design model of syrup manufacturing system contains three inputs. Membership function plot contains five regions for each input variable and these input variables: specific gravity, volume, and chemical selections maps with the MF,s which may lies in any of the five regions. Here we take the f_1 and f_2 as linguistic values of input volume and f_3 and f_4 as linguistic values of input variable specific gravity and f5 and f6 as linguistic values of input variable chemical selection. The mappings of these three inputs with the MF,s in all possible regions are presented in the table-3.12.

Table-3.12 All possible outputs of fuzzifier for the design model.

Input variable	Fuzzifier Output	Region-1	Region-2	Region-3	Region-4	Region-5
Volume	f_1	$F_1[1]$	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$
	f_2	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$	$F_1[6]$
Specific gravity	f_3	$F_2[1]$	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$
	f_4	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$	$F_2[6]$
Chemical Selection	f5	$F_3[1]$	$F_3[2]$	$F_3[3]$	$F_3[4]$	$F_3[5]$
	f6	$F_3[2]$	$F_3[3]$	$F_3[4]$	$F_3[5]$	$F_3[6]$

For the design model of syrup manufacturing system we use three inputs so the fuzzifier gives six outputs exposed in the figure-3.15, for these three input: specific gravity, volume, and chemical selections we use three fuzzifiers for the proposed syrup manufacturing design model.

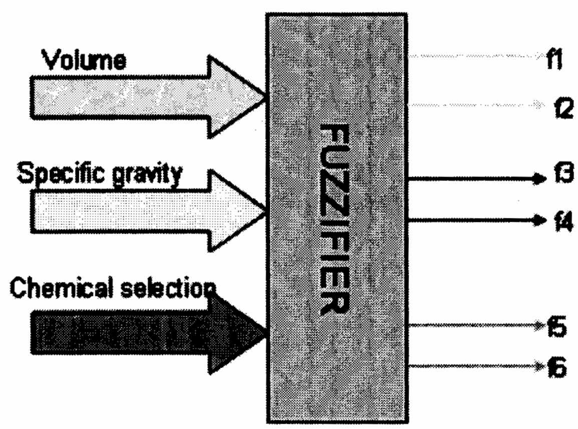


Figure-3.15 Design of fuzzifier for air conditioning model.

The linguistic output of fuzzifiers may exist in one of the five existing regions and each region is spited in to two parts; 1st half region and 2nd half region. Possible output of fuzzifier relation with these regions are presented in the table-3.13

Table-3.13 Fuzzifier output of linguistic variables for syrup manufacturing system.

Input	Fuzzifier Output	1st half region	2nd half region	Mid point Region	Starting region
Volume	f_1 f_2	$f_1 > f_2$	$f_1 < f_2$	$f_1 = f_2$	$f_1 = 1$ $f_2 = 0$
Specific Gravity	f_3 f_4	$f_3 > f_4$	$f_3 < f_4$	$f_3 = f_4$	$f_3 = 1$ $f_4 = 0$
Chemical Selection	f_5 f_6	$f_5 > f_6$	$f_5 < f_6$	$f_5 = f_6$	$f_5 = 1$ $f_6 = 0$

To verify the design model of syrup manufacturing the input fuzzy variable value are taken; viscosity=1.4, specific gravity=1.7 and chemical selection=16 this value of viscosity lies in the first half of second region and maps with the fuzzy variable medium and small, medium is taken as $F_1[3]$ and small is taken as $F_1[2]$ the value of specific gravity lies in the second half of the second region and maps with the fuzzy variable medium and small, medium is taken as $F_2[3]$, $F_2[2]$. Selected value of chemical selection lies in the send half of second region and maps with the fuzzy variable medium and small, medium is taken as $F_3[3]$, $F_3[2]$. Fuzzifier result for this model exposed in the table-3.14.

Table-3.14 Result of Fuzzifier calculation

Input Variable	**Value of input**	**Region**	**Fuzzy set Calculation**
Viscosity	1.4	2^{nd}	$F_1[3]=0.4$ $F_1[2]=1-F_1[3]$ $=0.6$
Specific Gravity	1.7	2^{nd}	$F_2[3]=0.3$ $F_2[2]=1-F_2[3]$ $=0.7$
Chemical Selection	17	2^{nd}	$F_3[3]=0.4$ $F_3[2]=1-F_3[3]$ $=0.6$

3.2.3 INFERENCE ENGINE

Inference engine takes six input values from the Fuzzifier and apply min-max composition and gives the eight values; R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, exposed in the figure-3.16.

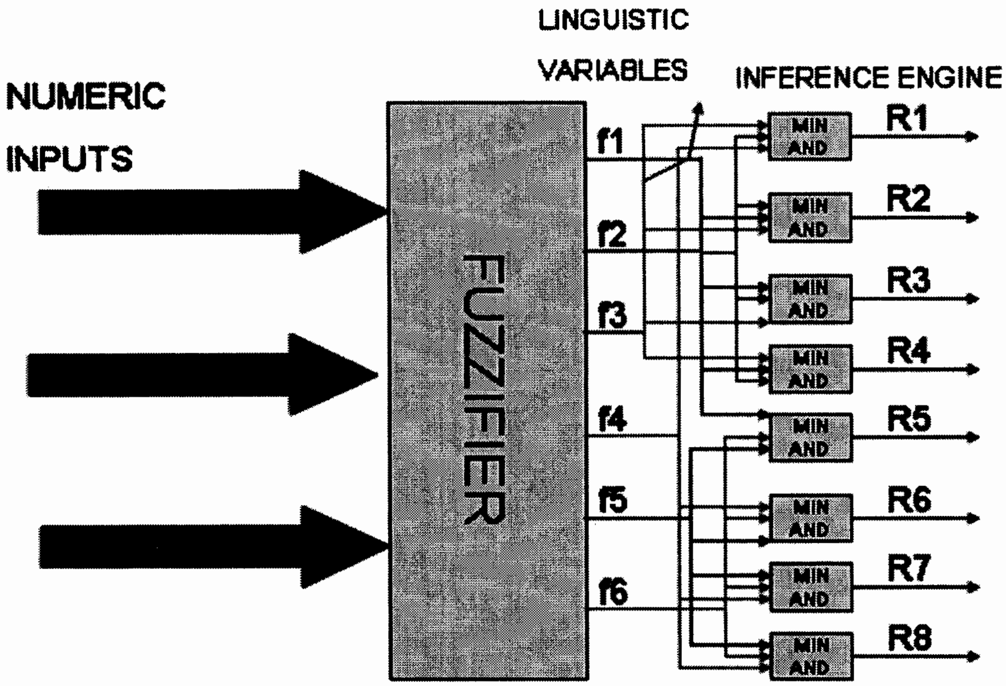


Figure-3.16 Inference engine design for syrup manufacturing system.

In the output membership function plot there are two overlapping regions, system designed with three inputs so total eight rules are applied for this proposed system [41]. Inference engine takes six input values from the fuzzifier and apply max-min composition and give eight values of R. in this case eight min-AND operations are applied to get the eight values of R.

R_1=F_1[3] and F_2[3] and F_3[3] = 0.4^0.3^0.4=0.3

R_2=F_1[2] and F_2[3] and F_3[3] = 0.6^0.3^0.4=0.3

R_3=F_1[3] and F_2[2] and F_3[3] = 0.4^0.7^0.4=0.4

R_4=F_1[2] and F_2[2] and F_3[3] = 0.6^0.7^0.4=0.4

R_5=F_1[3] and F_2[3] and F_3[2] = 0.4^0.3^0.6=0.3

R_6=F_1[2] and F_2[3] and F_3[2] = 0.6^0.3^0.6=0.3

R_7=F_1[3] and F_2[2] and F_3[2] = 0.4^0.7^0.6=0.4

R_8=F_1[2] and F_2[2] and F_3[2] = 0.6^0.7^0.6=0.6

3.2.4 RULE SELECTOR.

The rule base takes the three numeric values of inputs; volume, specific gravity and chemical selection and gives the eight singleton values by applying the fuzzy if-then rules [42], exposed in the figurer-3.17.

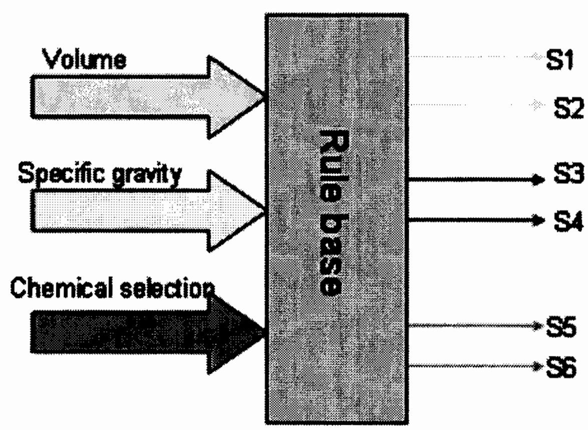


Figure-3.17 Design model of input and output of rule base for syrup manufacturing System.

In the output membership functions plot there two overlapping regions and three inputs are used for system so total eight rules are required, presented in the table-3.15.

Table-3.15 Design rules for system

No	Viscosity	Specific Gravity	Chemical Selected	Tem.	Tem. Time	Mixing speed	Mixing Time	valve	Valve opening time	PH	PH time
1	SMALL	SMALL	MEDIUM	LOW	LONG	FAST	LONG	FEW	LONG	MEDIUM	LONG
2	MEDIUM	SMALL	MEDIUM	LOW	MEDIUM	FAST	MEDIUM	FEW	MEDIUM	NORMAL	MEDIUM
3	SMALL	MEDIUM	MEDIUM	MEDIUM	LONG	VERY FAST	LONG	FEW	LONG	MEDIUM	LONG
4	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	VERY FAST	MEDIUM	FEW	MEDIUM	NORMAL	MEDIUM
5	SMALL	SMALL	SMALL	LOW	LONG	FAST	LONG	MEDIUM	LONG	MEDIUM	LONG
6	MEDIUM	SMALL	SMALL	LOW	MEDIUM	FAST	MEDIUM	MEDIUM	MEDIUM	NORMAL	MEDIUM
7	SMALL	MEDIUM	SMALL	MEDIUM	LONG	VERY FAST	LONG	MEDIUM	LONG	MEDIUM	LONG
8	MEDIUM	MEDIUM	SMALL	MEDIUM	MEDIUM	VERY FAST	MEDIUM	MEDIUM	MEDIUM	NORMAL	MEDIUM

Singleton values obtained from knowledge base for applied, presented in the table-3.16.

Table-3.16 Singleton values

Singleton Value	Tem.	Tem. Time	Mixing speed	Mixing Time	PH	PH time	valve	Valve Opening Time
S_1	0.3	0.7	0.7	0.7	0.5	0.7	0.3	0.7
S_2	0.3	0.5	0.7	0.5	0.3	0.5	0.3	0.5
S_3	0.5	0.7	1	0.7	0.5	0.7	0.3	0.7
S_4	0.5	0.5	1	0.5	0.3	0.5	0.3	0.5
S_5	0.3	0.7	0.7	0.7	0.5	0.7	0.5	0.7
S_6	0.3	0.5	0.7	0.5	0.3	0.5	0.5	0.5
S_7	0.5	0.7	1	0.7	0.5	0.7	0.5	0.7
S_8	0.5	0.5	1	0.5	0.3	0.5	0.5	0.5

Rule base block for the design model of syrup manufacturing system contains lookup table, it consists of rules which are design for model. Three comparators, three detectors and three decoders , these detectors and decoders tells about the region maps by the input variable and response of fuzzy set to these variable. Comparator takes information's from detectors and decoders and gives the singleton values, exposed in the figure-3.18.

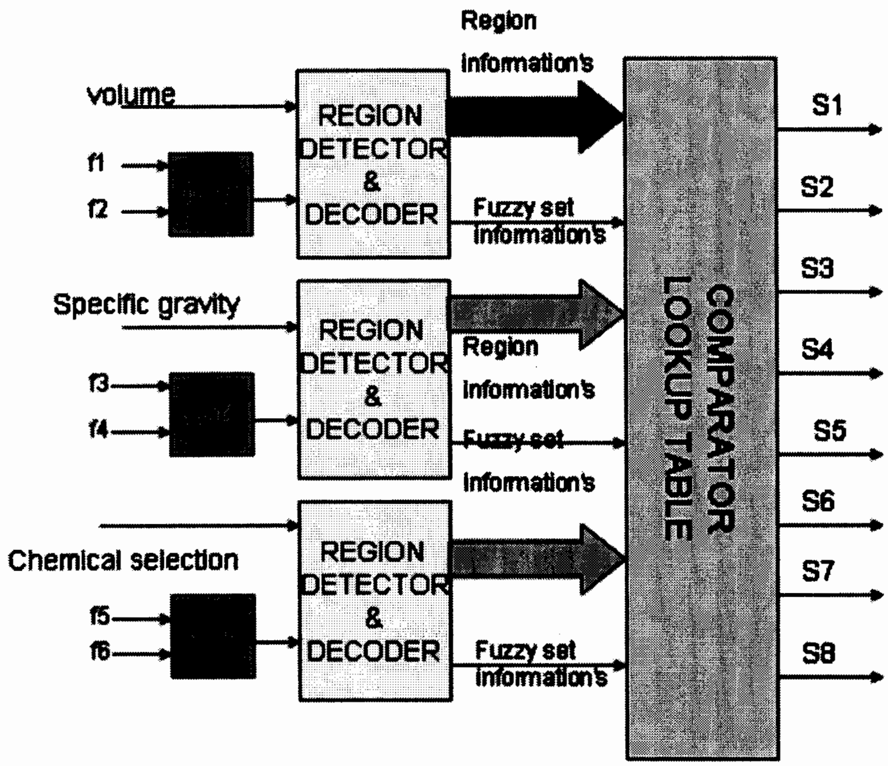


Figure-3.18 Arrangement of rule base to get singleton values for syrup manufacturing system.

3.2.5 DEFUZZIFICATION.

The conversion of linguistic variables in to crisp/numeric values is known as defuzzification. The method used for defuzzification is (COA) center of average

Whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Where i =1, 2, 3, 4.................

For the designed syrup manufacturing system eight defuzzifiers are used, for eight output variables. This system takes sixteen inputs to each defuzzifier eight from inference engine i.e. R_1, R_2, R_3, R_4, R_5, R_6, R_7, and R_8 and eight from the rule base i.e. S_1, S_2, S_3, S_4 S_5, S_6, S_7, and S_8, and gives the crisp value of output variables. Exposed in the figure-3.18.

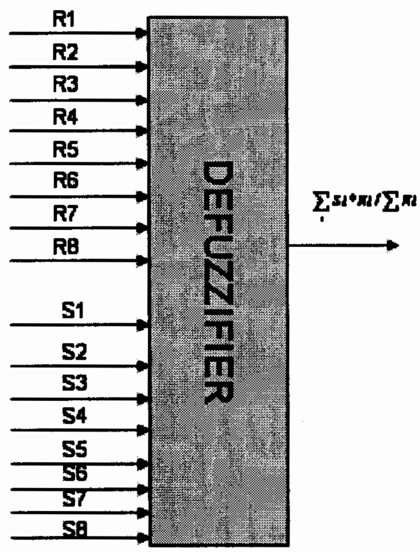


Figure-3.18 Arrangement of rule base to get singleton values for syrup manufacturing

The modeling of defuzzifier is exposed in the figure-3.20; one defuzzifier contains adder, multipliers and divider. For the air conditioning system we require four multiplies, two adders and one divider to implement the COA method.

3.2.6 EXPERIMENTAL ARRANGEMENT.

The experimental arrangements for the designed syrup manufacturing system is exposed in the figure-3.21.

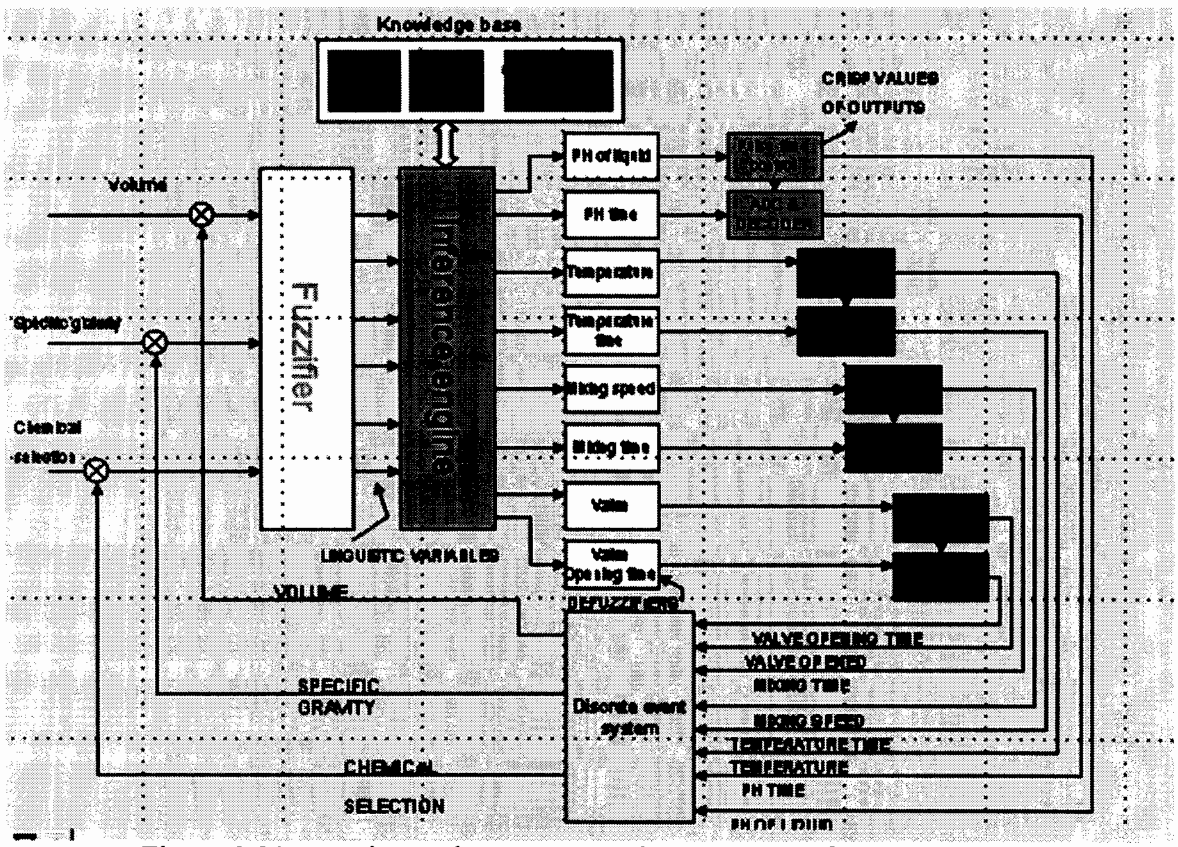


Figure-3.21 Experimental arrangement for syrup manufacturing system.

3.3 DESIGN OF ICE-CREAM MANUFACTURING SYSTEM USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM.

Ice cream is an important and very popular dairy product which is found in many flavors. The proposed Ice-cream manufacturing plant is designed to facilitate the ice cream manufacturing industry

3.3.1. DESIGN ALGORITHM.

The ice-cream manufacturing system is designed with two inputs volume and ingredients selection, and six outputs heating/cooling temperature, temperature time, valve, valve opening time, , mixing speed, mixing time, each input plot contains six membership functions and five regions the name of membership functions and their ranges were exposed in the table—3.17.

Table-3.17 Input MF and their ranges values.

NO	Membership Function	Volume dyn:s/cm²	ingredients selection
1	Very small	0-10	0-10
2	Small	0-40	0-20
3	Medium	20-60	10-30
4	Above medium	40-80	20-40
5	High	60-100	30-50
6	Very high	80-100	40-50

In response of ingredients selection valve are open, installed at the feed lines for material constituents flow.

Plot of input MF,s . For volume is exposed in the figure-3.22 there are six MF,s $F_1[1]$, $F_1[2]$, $F_1[3]$, $F_1[4]$, $F_1[5]$, and $F_1[6]$ and five regions

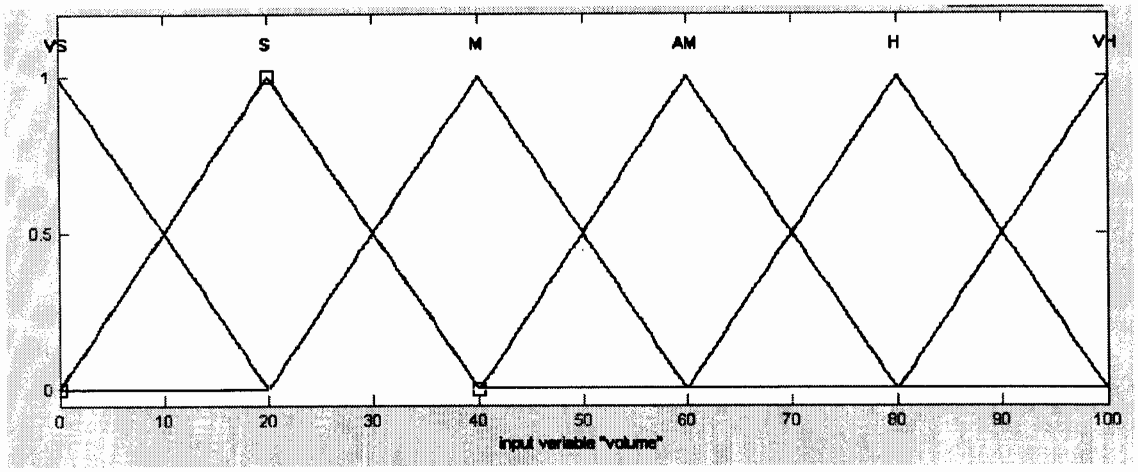


Figure-3.22 Input MF function volume plot

Plot of input MF,s for ingredients selection contains six MF, s $F_2[1]$, $F_2[2]$, $F_2[3]$, $F_2[4]$, $F_2[5]$, $F_2[6]$ and five regions input numeric value of ingredients selection lies in any one of the five region as exposed in the figure-3.23. In the response of its value valves are open which are installed at the feed lines for material constituents flow.

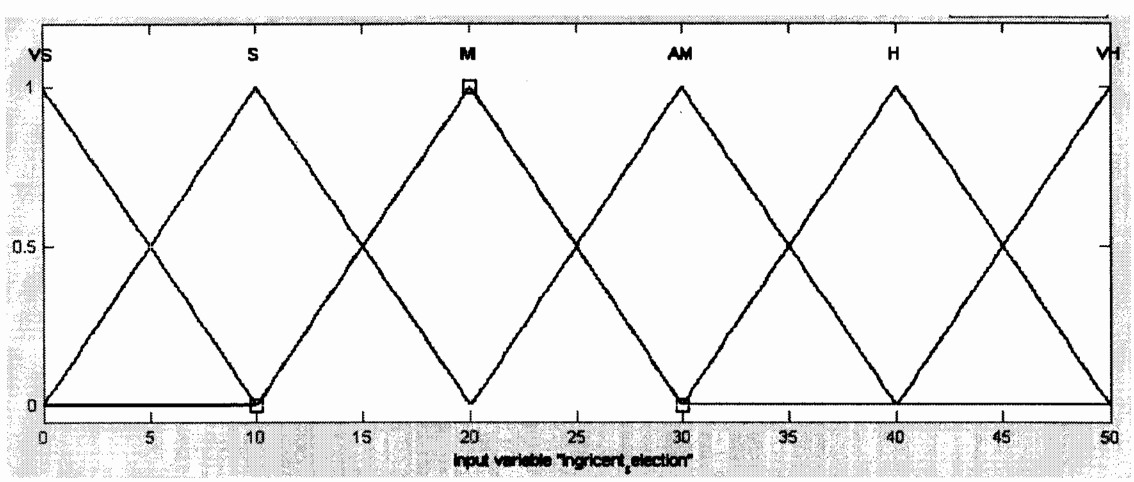


Figure-3.23 Input MF plot for ingredient selection

Plot of output MF,s exposed in the figure-3.24 and in the figure-3.25 for the convenience in calculation the range values of output membership function for mixing speed, mixing time, valve selection, valve opening time, heating/cooling temperature, Temperature time are taken same, plot contains five output MF, s and four regions

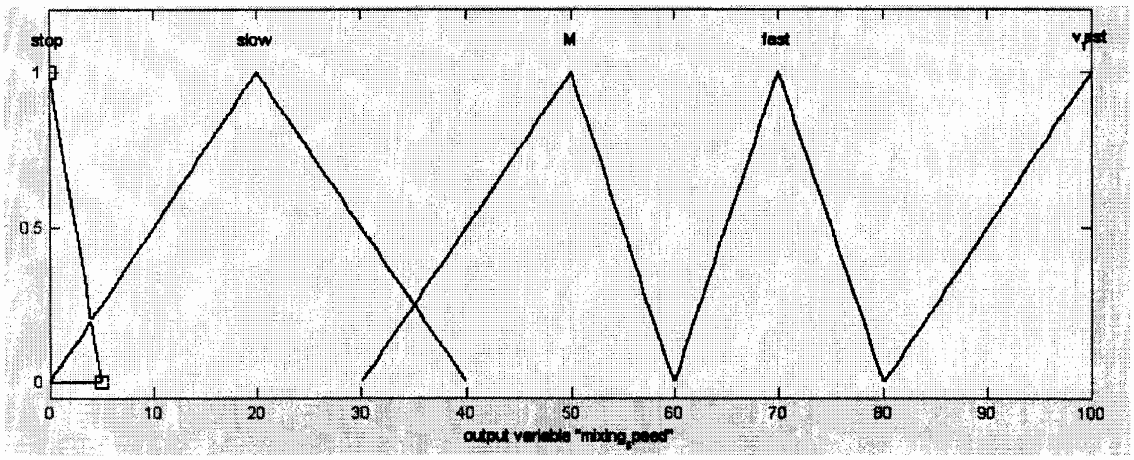


Figure-3.24 Output MF plot for mixing speed.

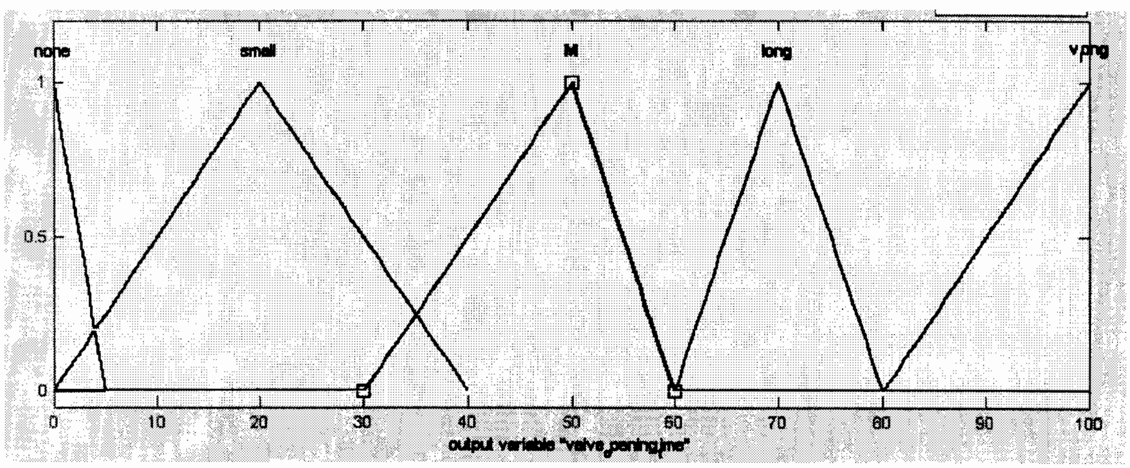


Figure-3.25 Plot of output MF,s for valve-opening time.

The MS,s and ranges of six output variables values were presented in the table-3.18.

Table-3.19 All possible outputs of fuzzifier for the design model.

Input variable	Fuzzifier Output	Region-1	Region-2	Region-3	Region-4	Region-5
Volume	F_1	$F_1[1]$	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$
	F_2	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$	$F_1[6]$
Ingredient selection	F_3	$F_2[1]$	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$
	F_4	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$	$F_2[6]$

For the design model of ice-cream manufacturing system we use two inputs so the fuzzifier gives four outputs was exposed in the figure-3.26, for these two input variables two fuzzifiers are used in this design model.

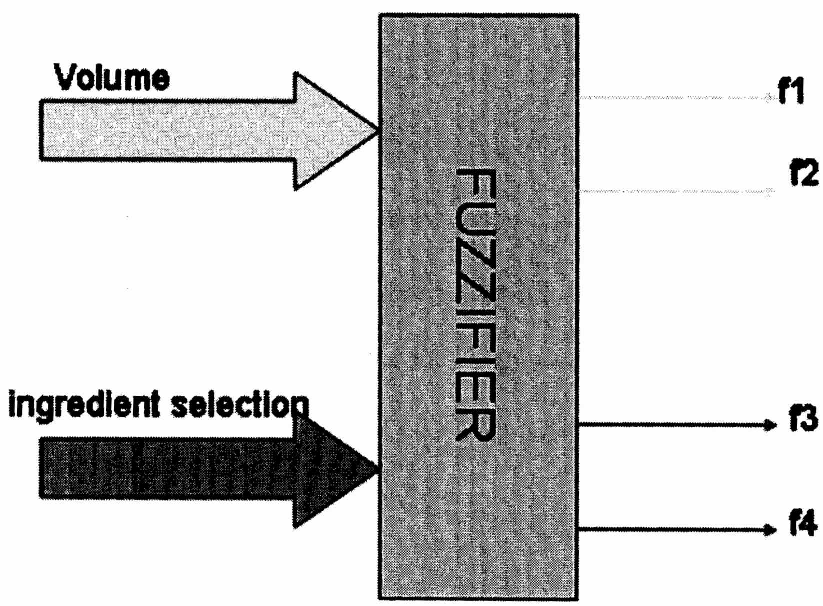


Figure-3.26 Design of fuzzifier for ice cream manufacturing system.

The linguistic output of fuzzifiers may exist in any the five regions and each region is spited in to two parts; 1st half region and 2nd half region. Possible output of fuzzifiers relation with these regions were presented in the table-3.20

Table-3.20 Fuzzifier output of linguistic variables for ice-cream manufacturing system.

Input	Fuzzifier Output	1st half Region	2nd half region	Mid point Region	Starting region
Volume	f_1 f_2	$f_1 > f_2$	$f_1 < f_2$	$f_1 = f_2$	$f_1 = 1$ $f_2 = 0$
Ingredient Selection	F3 f_4	$f_3 > f_4$	$f_3 < f_4$	$f_3 = f_4$	$f_3 = 1$ $f_4 = 0$

To verify the design model of ice-cream manufacturing system the input fuzzy variables value are taken; volume=28, ingredients selection=27 this values of volume exist in the first part of second region and maps with the fuzzy variable medium and small, medium is taken as $F_1[3]$ and small is taken as $F_1[2]$. Selected value of chemical selection lies in the second half of third region and maps with the fuzzy variable; above medium and medium, above medium is taken as $F_3[3]$, and medium is taken as $F_3[2]$. Fuzzifier result for this proposed system were exposed in the table-3.2

Table-3.21 Result of Fuzzifier calculation

Input Variable	Value of input	Region	Fuzzy set Calculation
Volume	28	2nd	F[1]=0.4 F[2]=1-F_1[3]=0.6
Ingredients Selection	27	3rd	F[3]=0.3 F[4]=1-F_3[3]=0.7

3.3.3 INFERENCE ENGINE

Inference engine takes four inputs from fuzzification apply the min-and operation and gives the six values i.e. R_1, R_2, R_3, R_4, R_5 and R_6 were exposed in the figure-3.27

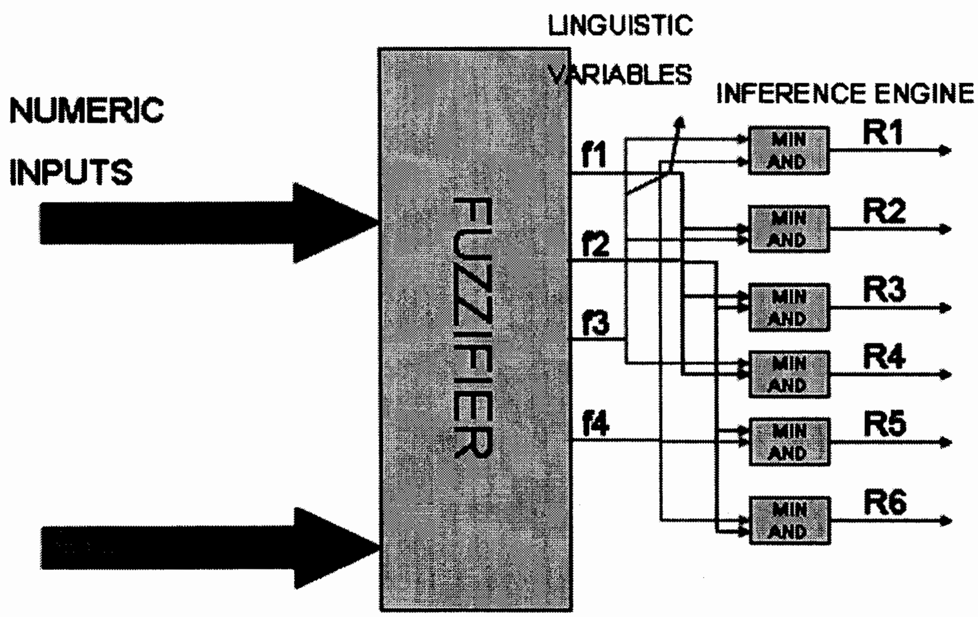


Figure-3.27 inference engine design for ice-cream manufacturing.

In the output membership function plot there are three overlapping regions, system designed with two inputs so total nine rules are applied for this proposed system [41]. But for each value of input variables i.e. for volume = 28, ingredient selection = 27.

Inference engine takes four input values from the fuzzifiers and apply max-min composition and gives the six values of R. In this case four min-AND operations are applied to get the six values of R.

R_1=F [1] and F [3] = 0.4 and 0.3 = 0.3

R_2=F [1] and F [4] = 0.4 and 0.7 = 0.4

R_3=F [2] and F [3] = 0.6 and 0.3 = 0.3

R_4=F [2] and F [4] = 0.6 and 0.7 = 0.6

R_5=F [3] and F [4] = 0.3 and 0.7 = 0.3

R_6=F [1] and F [2] = 0.6 and 0.4 = 0.4

3.3.4 RULE SELECTOR

The rule base receives the two crisp values of inputs; VOLUME and INGREDIENT SELECTION and gives the six singleton values by applying the if-then rules [42], were exposed in the figurer-3.28

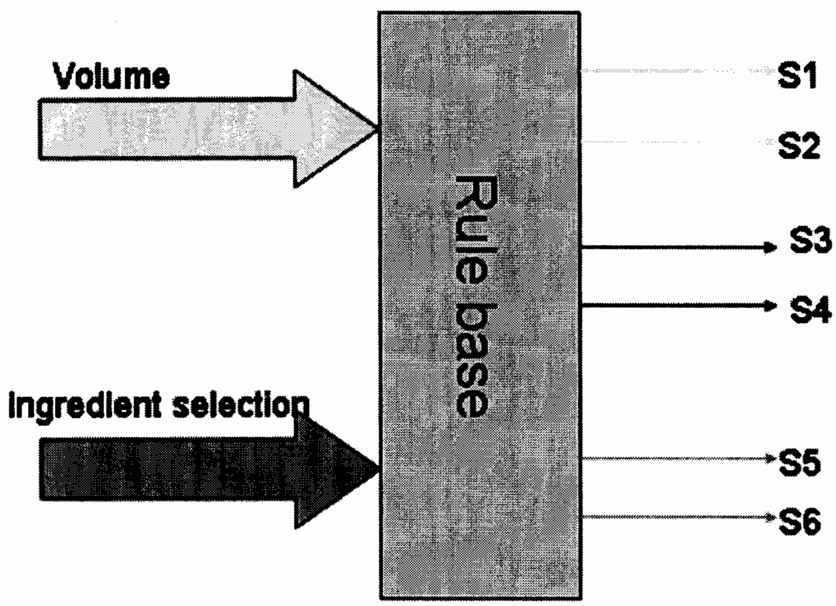


Figure-3.28 Designed model of input and output of rule base for ice-cream manufacturing system.

In the output membership functions plot there three overlapping regions and two inputs are used for system so total nine rules are required which were presented in the table-3.22

Table—3.22 rules designed for system

NO	VOLUME	INGREDIENT SELECTION	TEMPERATURE	TEMP. TIME	VALVE SELECTION	VALVE OPENING TIME	MIXING SPEED	MIXING TIME
1	SMALL	MEDIUM	MEDIUM	LONG	MEDIUM	LONG	FAST	LONG
2	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	FAST	MEDIUM
3	SMALL	ABOVE MEDIUM	LOW	LONG	MEDIUM	LONG	MEDIUM	LONG
4	MEDIUM	ABOVE MEDIUM	LOW	MEDIUM	FEW	MEDIUM	MEDIUM	MEDIUM
5	SMALL	MEDIUM	MEDIUM	LONG	FEW	LONG	FAST	LONG
6	MEDIUM	MEDIUM	MEDIUM	MEDIUM	FEW	MEDIUM	FAST	MEDIUM
7	SMALL	ABOVE MEDIUM	LOW	LONG	MEDIUM	LONG	MEDIUM	LONG
8	MEDIUM	ABOVE MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
9	SMALL	MEDIUM	MEDIUM	LONG	MEDIUM	LONG	FAST	LONG

Corresponding to these rules six singleton values; S1, S2, S3, S4, S5 and S6 are obtained which are listed in table-3.23

Table—3.23 Singleton values for outputs

Singleton Values	Temperature	Temp. Time	Valve Selection	Valve Opening Time	Mixing Speed	Mixing Time
S1	0.5	0.7	0.5	0.7	0.7	0.7
S2	0.5	0.5	0.5	0.5	0.7	0.5
S3	0.2	0.7	0.5	0.7	0.5	0.7
S4	0.2	0.5	0.2	0.5	0.5	0.5
S5	0.5	0.7	0.2	0.7	0.7	0.7
S6	0.5	0.5	0.2	0.5	0.7	0.5

Rule base block for the design model of ice cream manufacturing system contains lookup table, it consists of rules which are design for model. Two comparators, two detectors and two decoders , these detectors and decoders tells about the region maps by the input variable and response of fuzzy set to these variable. Comparator takes information's from detectors and decoders and gives the singleton values, was exposed in the figure-3.29

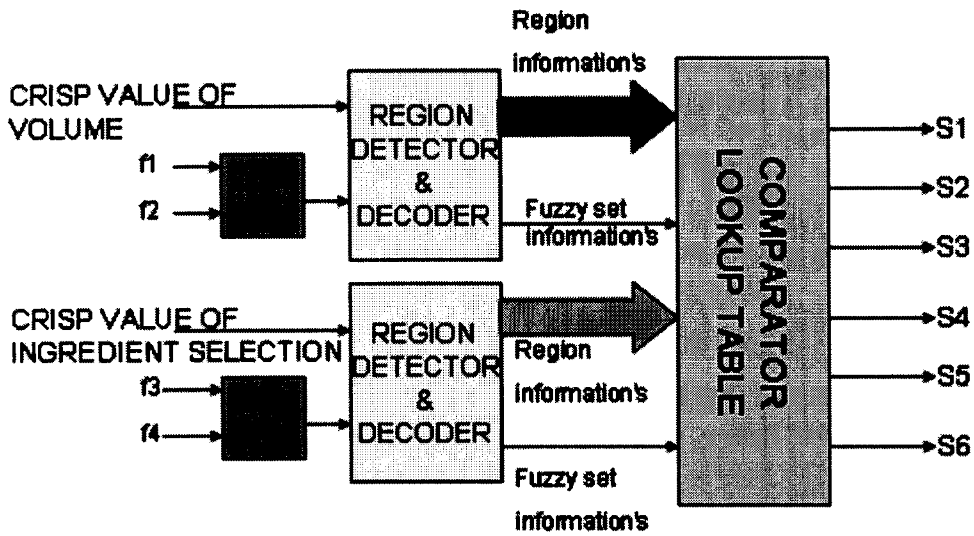


Figure-3.29 Arrangement of rule base to get singleton values for ice cream manufacturing system.

3.3.5 DEFUZZIFICATION.

The conversion of linguistic variables in to crisp/numeric values was done by using defuzzification. Many methods were used for this defuzzification purpose e.g. (MOM) mean of maximum. (SOM) smallest of maximum (LOM) left of maximum etc.

The method used for defuzzification is (COA) center of average

Whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Where i =1, 2, 3, 4, 5, 6

For the designed ice cream manufacturing system six defuzzifiers are used, for the six outputs. This system takes twelve inputs to each defuzzifier six from inference engine i.e. R_1, R_2, R_3, R_4,

R_5, and R_6, and six from the rule base i.e. S_1, S_2, S_3, S_4, S_5, and S_6 and gives the crisp values of outputs. As exposed in the figure-3.30

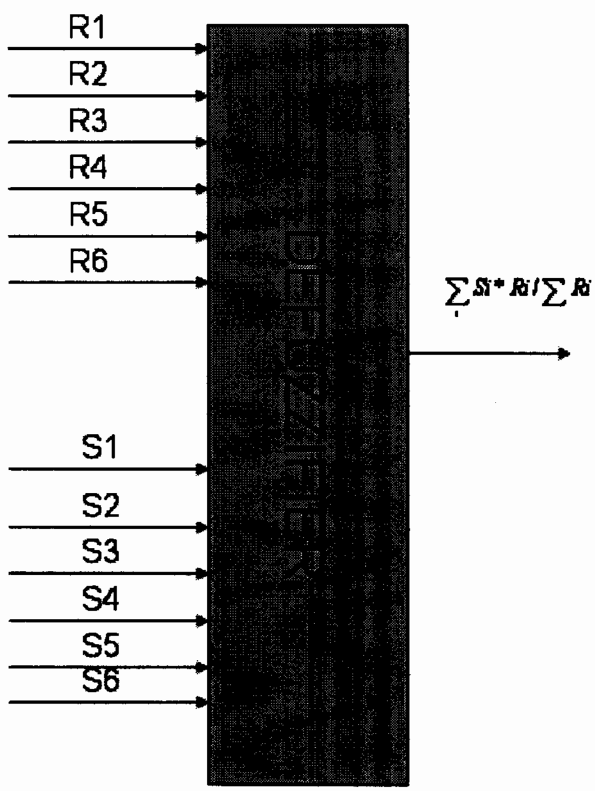


Figure-3.30 Block diagram of defuzzifier for ice cream manufacturing system.

The modeling of defuzzifier was exposed in the figure-3.31; one defuzzifier contains adder, multipliers and divider. For the ice cream manufacturing system we require six multiplies, two adders and one divider to implement the COA method.

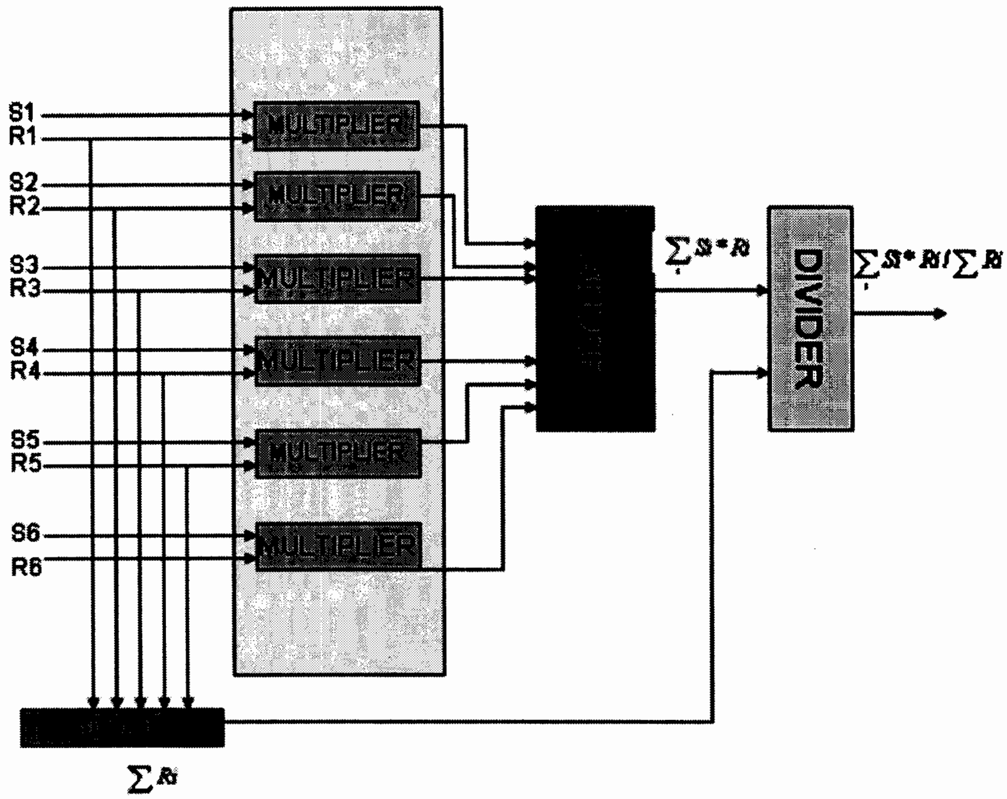


Figure-3.31 Modeling of defuzzifier for ice cream manufacturing system

3.3.6 EXPERIMENTAL ARRANGEMENT.

The experimental arrangements for the designed ice-cream manufacturing system was exposed in the figure-3.33

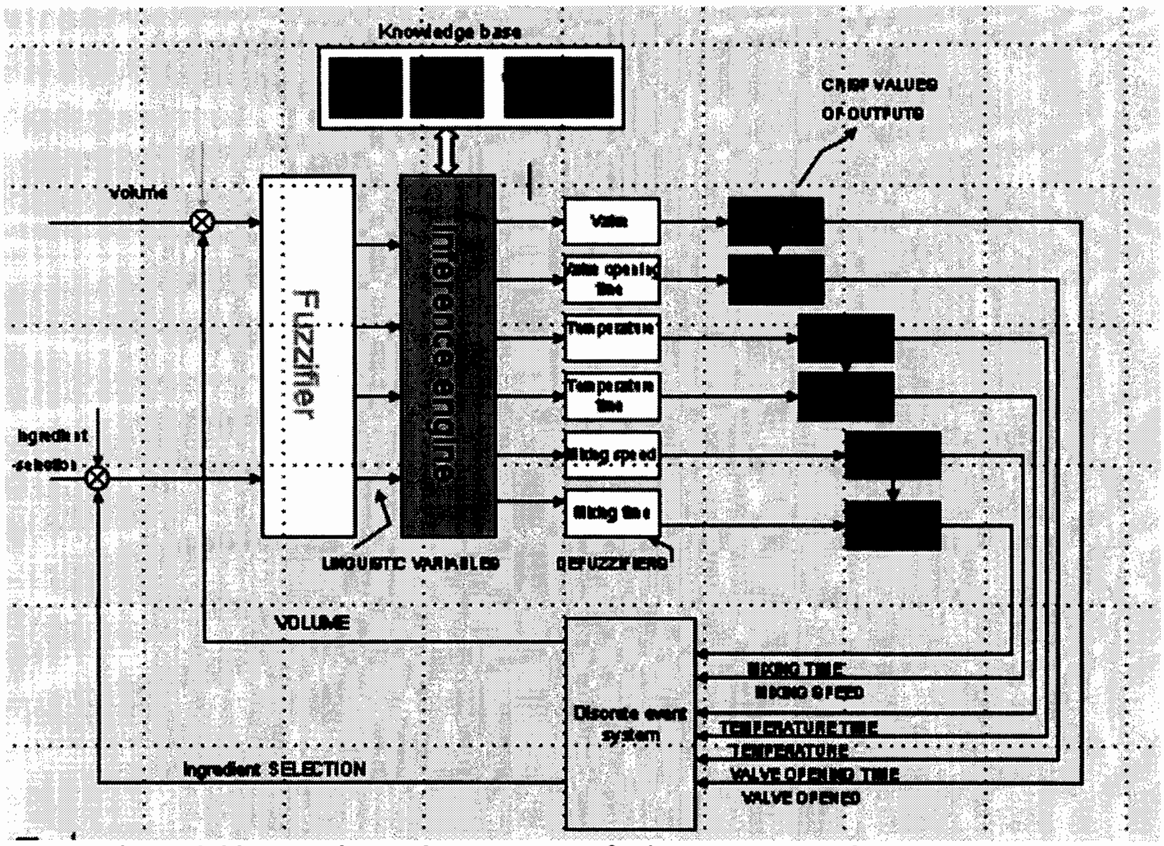


Figure-3.33 Experimental arrangement for ice-cream manufacturing system.

3.4 SOAP MANUFACTURING SYSTEM USING FUZZY TIME CONTROL DISCRETE EVENT SYSTEM.

Soap is an important anionic detergent which comes in many different shapes and forms like liquid, powder and solid bar. The proposed soap manufacturing plant was designed using fuzzy time control discrete event techniques to facilitate the soap manufacturing industry.

3.4.1. DESIGN ALGORITHM.

The soap manufacturing system is designed with four inputs; viscosity, specific gravity, chemical selection and volume and eight outputs; heating/cooling temperature, temperature time, valve selection, valve opening time, PH at current liquid temperature, PH time, mixing speed, mixing time, each input plot contains six membership functions and five regions the name of membership functions and their ranges were exposed in the table-3.24

Table-3.24 Input MF and their ranges

Membership Function	Volume	Viscosity $dyn.s/cm^2$	Specific Gravity Mg/ml	Chemical selection
Very small	0-20	0-200	0-2	0-10
Small	0-40	0-400	0-4	0-20
Medium	20-60	200-600	2-6	10-30
Above medium	40-80	400-800	4-8	20-40
High	60-100	600-1000	6-10	30-50
Very high	80-100	800-1000	8-10	40-50

In response of chemical selection valve are opened, installed at the feed lines for material constituents flow. In the designed model liquid soap mixing and storing device a discharge valve is designed with the pipe lines communicating between the discharge valve and mixing/ storing tank. Air supply is also provided to the liquid soap through piping system and the both (air and liquid soap) are mixed and agitated in the mixing chamber to remove the air bubbles in the liquid soap mixture. A pressuring device is arranged with the airing device to maintain the pressure of air agitated with the soap [44]. So in this way a proper mixing and storing tank can be designed for increasing quality based efficacy of liquid soap.

Plot of input membership functions (MF) for specific gravity was exposed in the figure-3.34 there are six MF,s $F_1[1]F_1[2]F_1[3]F_1[4]F_1[5]F_1[6]$ and five regions

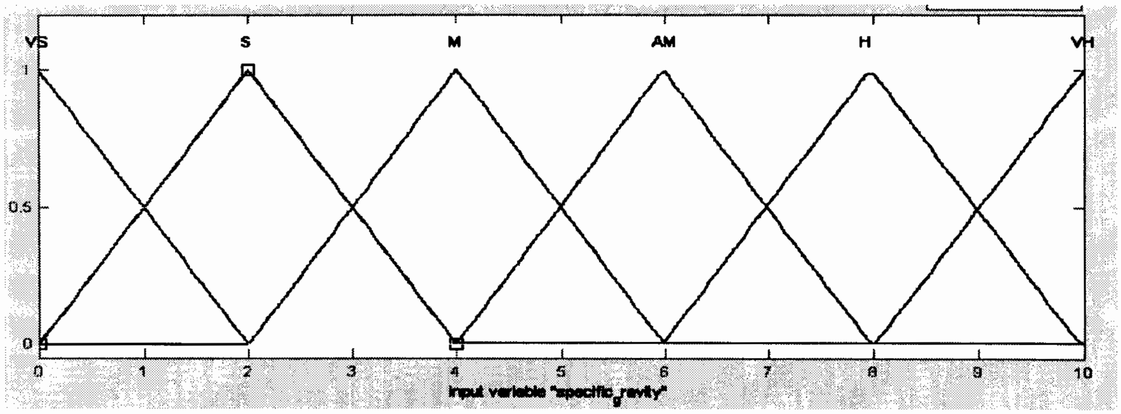


Figure-3.34 Input MF function specific gravity plot

Plot of input MF viscosity contains six MF,s $F_2[1]$, $F_2[2]$, $F_2[3]$, $F_2[4]$, $F_2[5]$, $F_2[6]$ and five regions input numeric value of viscosity exist in one of the five existing regions as exposed in the figure-3.35.

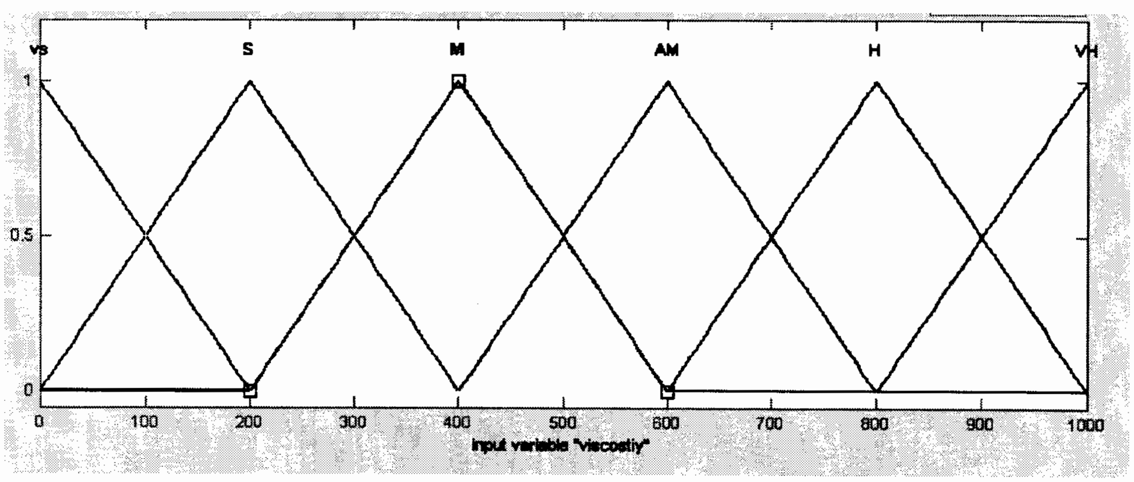


Figure-3.35 Input MF plot for viscosity

Plot of input MF chemical selection contains six MF,s $F_3[1]$ $F_3[2]$, $F_3[3]$, $F_3[4]$, $F_3[5]$, $F_3[6]$ and five regions as exposed in the figure-3.36

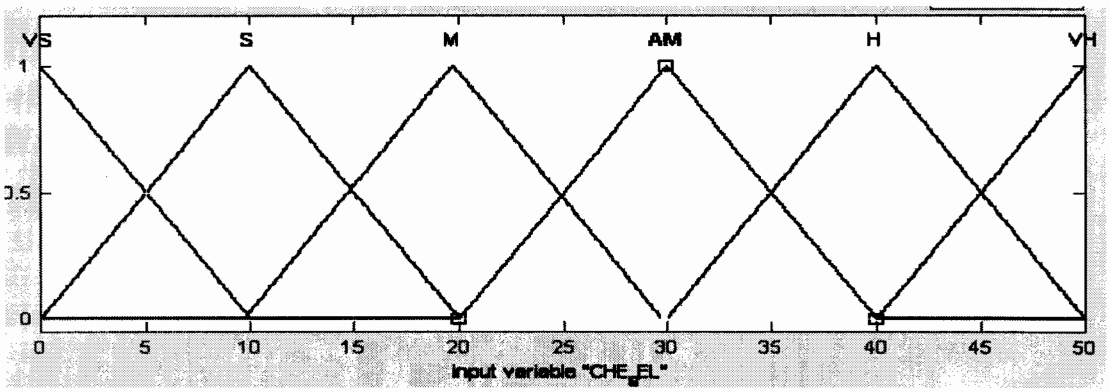


Figure-3.36 Input MF plot of chemical selection

Plot of input MF,s for the volume was exposed in the figure-3.37 plot contains six MF,s $F_4[1]$, $F_4[2]$, $F_4[3]$, $F_4[4]$, $F_4[5]$ and $F_4[6]$ and five regions given input value may exist in one of the five existing regions.

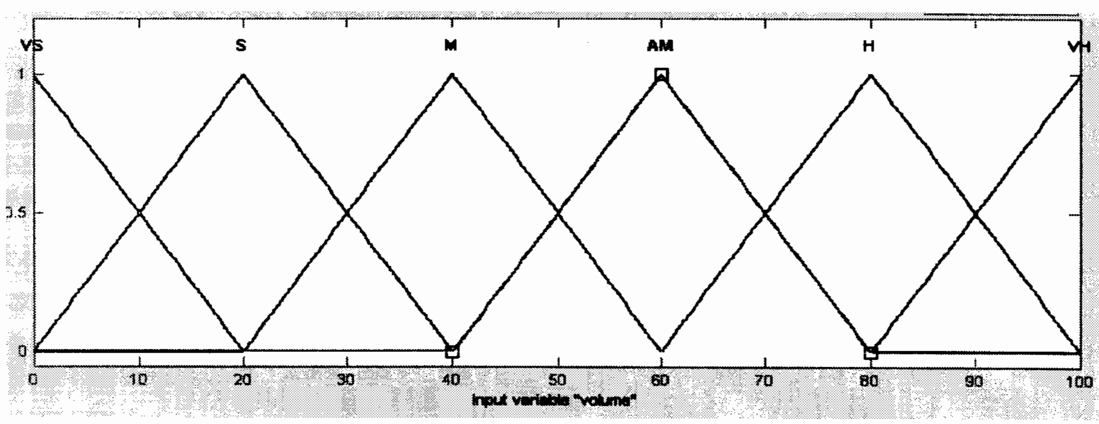


Figure- 37 Plot of input membership functions for volume

Plot of output MF,s were exposed in the figure-3.38 for the convenience in calculation the range values of output MF,s for mixing speed, mixing time, valve selection, valve opening time, PH at given temperature, PH time, Temperature, Temperature time are taken same, plot contains five output MF, s and four regions

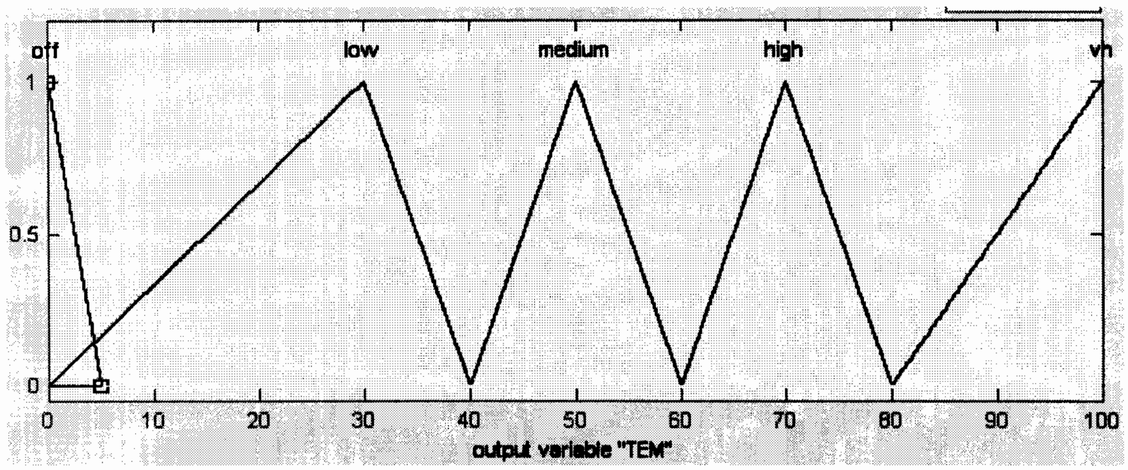


Figure-3.38 Output MF plot

The MF,s and ranges values of the eight output variables were presented in the table-3.25.

Table-3.25 Output membership functions and their ranges.

Membership Function	Range	Temperature	Temperature Time	PH	PH time	Value	Valve Opening time	Mixing speed	Mixing Time
MF1	0-5	Off	None	Small	None	None	None	Stop	None
MF2	0-40	Low	Small	Normal	Small	Few	Small	Slow	Small
MF3	40-60	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
MF4	60-80	High	Long	High	Long	Large	Long	Fast	Long
MF5	80-100	Very-high	Very-long	Very High	Very-long	Very large	Very-long	Very fast	Very-long

3.4.2 FUZZIFICATION

First step in the design model is the fuzzification in which numeric inputs are given to the fuzzifiers which converts these numeric inputs to the linguistic variables. The design model of soap manufacturing system contains four inputs. Membership functions plot contains five regions for each input variable and these input variables maps with the membership functions which may lies in any of the five regions. Here we take the f_1 and f_2 as linguistic values of input volume and f_3 and f_4 as linguistic values of input variable specific gravity and f5 and f6 as linguistic values of input variable chemical selection and f7 and f8 as linguistic values of input variable viscosity. The mappings of input variables with the membership functions in all possible regions

are given in table-3.26

Table-3.26 All possible outputs of fuzzifier for the design model.

Input variable	Fuzzifier Output	Region-1	Region-2	Region-3	Region-4	Region-5
Volume	f_1	$F_1[1]$	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$
	f_2	$F_1[2]$	$F_1[3]$	$F_1[4]$	$F_1[5]$	$F_1[6]$
Specific gravity	f_3	$F_2[1]$	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$
	f_4	$F_2[2]$	$F_2[3]$	$F_2[4]$	$F_2[5]$	$F_2[6]$
Chemical Selection	f_5	$F_3[1]$	$F_3[2]$	$F_3[3]$	$F_3[4]$	$F_3[5]$
	f_6	$F_3[2]$	$F_3[3]$	$F_3[4]$	$F_3[5]$	$F_3[6]$
Viscosity	f_7	$F_4[1]$	$F_4[2]$	$F_4[3]$	$F_4[4]$	$F_4[5]$
	f_8	$F_4[2]$	$F_4[3]$	$F_4[4]$	$F_4[5]$	$F_4[6]$

For the design model of soap manufacturing system we use four inputs so the fuzzifiers gives eight outputs as shown in the figure-3.39, for these four input variables four fuzzifiers are used in this design model.

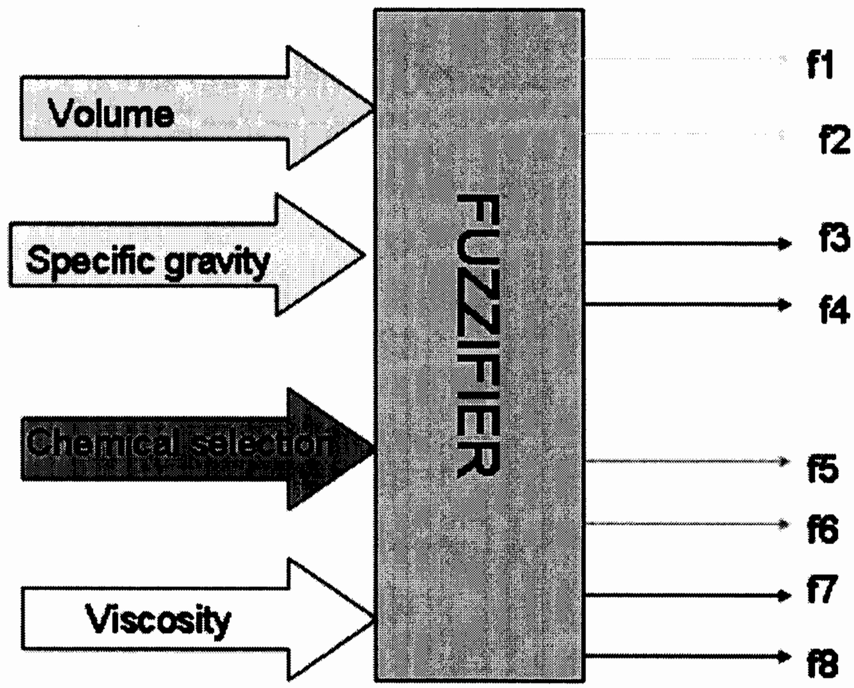


Figure-3.39 Design of fuzzifier for soap manufacturing system.

The linguistic output of fuzzifiers lies in any of the five regions; each region is divided in to two halves; 1st half region and 2nd half region. Possible output of fuzzifiers relation with these regions are given in table-3.27

Table-3.27 Fuzzifiers output of linguistic variables for soap manufacturing system.

Input	Fuzzifier Output	1st half Region	2nd half region	Mid point Region	Starting region
Volume	f_1 f_2	$f_1 > f_2$	$F_1 < f_2$	$f_1 = f_2$	$f_1 = 1$ $f_2 = 0$
Specific Gravity	f_3 f_4	$f_3 > f_4$	$F_3 < f_4$	$f_3 = f_4$	$f_3 = 1$ $f_4 = 0$
Chemical Selection	f_5 f_6	$f_5 > f_6$	$F_5 < f_6$	$f_5 = f_6$	$f_5 = 1$ $f_6 = 0$
Viscosity	f_7 f_8	$f_7 > f_8$	$F_7 < f_8$	$f_7 = f_8$	$f_7 = 1$ $f_8 = 0$

To verify the design model of soap manufacturing the input fuzzy variable value are taken; viscosity=850, specific gravity=1.5, chemical selection=14 and volume=9 this value of viscosity lies in the first half of fifth region and maps with the fuzzy variable HIGH and VERY-HIGH, HIGH is taken as $F_4[5]$ and VERY-HIGH is taken as $F_4[6]$ the value of specific gravity lies in the second half of the first region and maps with the fuzzy variable SMALL and VERY-SMALL, SMALL is taken as $F_2[2]$ and VERY-SMALL is taken as $F_2[1]$. Selected value of chemical selection lies in the first half of second region and maps with the fuzzy variable MEDIUM and SMALL, MEDIUM is taken as $F_3[3]$, $F_3[2]$. Selected value of volume lies in the 1st half of the first region which map with the fuzzy variables SMALL and VERY-SMALL. Here SMALL is taken as F_1 [2] and VERY-SMALL is taken as F_1 [1]. Fuzzifier result for this model are shown in table-3.28

Table-3.28 Result of Fuzzifier calculation for soap manufacturing system

Input Variable	Value of input	Region	Fuzzy set Calculation
Volume	9	1ST	$F_1[1]=0.55$ $F_1[2]=1-F_1[1]$ $=0.45$
Specific Gravity	1.5	1ST	$F_2[2]=0.75$ $F_2[1]=1-F_2[2]$ $=0.25$
Chemical Selection	14	2nd	$F_3[3]=0.6$ $F_3[2]=1-F_3[3]$ $=0.4$
Viscosity	850	5TH	$F_4[5]=0.75$ $F_4[6]=1-F_4[5]$ $=0.25$

3.4.3 INFERENCE ENGINE

Inference engine takes eight input values from the Fuzzifiers and apply min-max composition and gives the sixteen values; R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15} and R_{16},as shown in the figure-3.40.

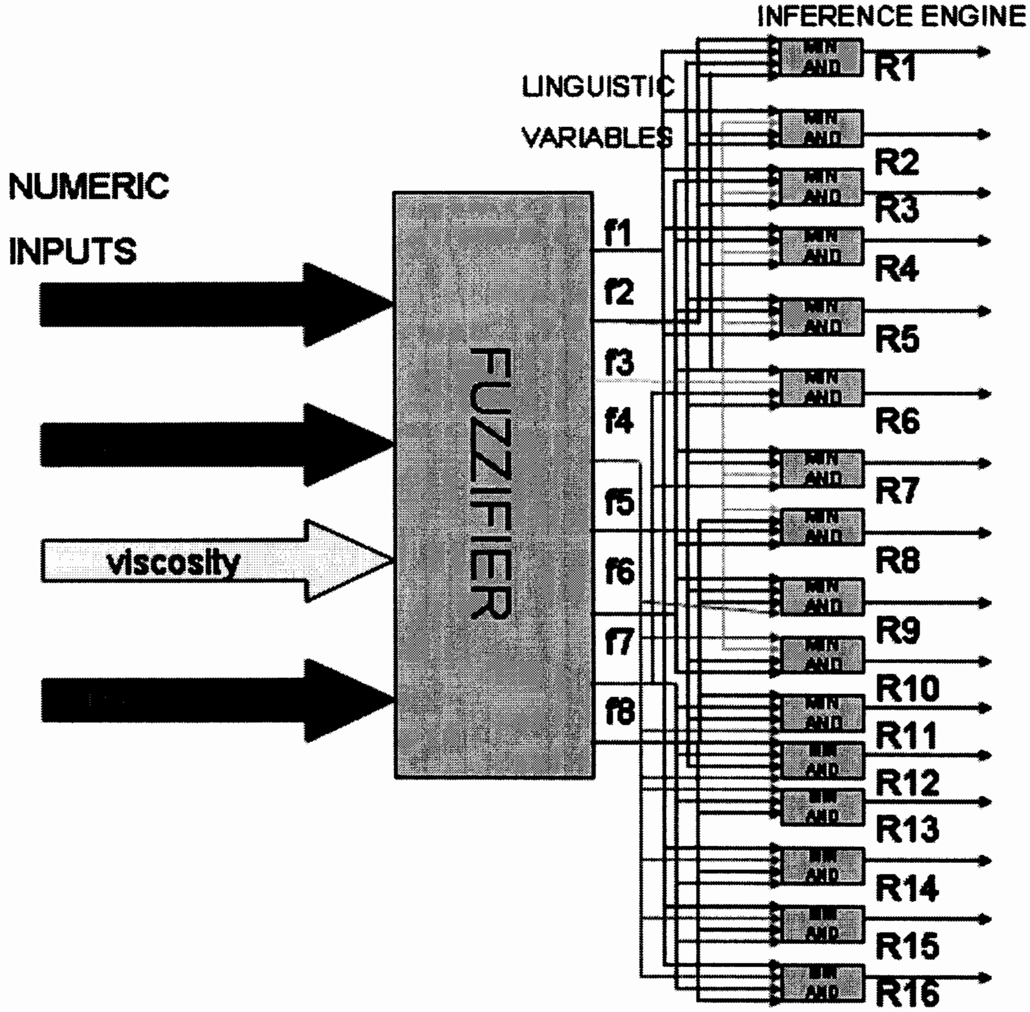


Figure-3.40 Inference engine design for soap manufacturing systeml.

In the output membership function plot there are two overlapping regions, system designed with four inputs so total sixteen rules are applied for this proposed system [41].

Inference engine takes eight input values from the fuzzifiers and apply max-min composition and give sixteen values of R. in this case sixteen min-AND operations are applied to get the sixteen values of R.

R_1=F_1[1]^F_2[1]^F_3[2]^F_4[5] = 0.55^0.25^0.4^0.75=0.25

R_2=F_1[1]^F_2[2]^F_3[3]^F_4[5] = 0.55^0.75^0.6^0.75=0.55

R_3=F_1[1]^F_2[2]^F_3[2]^F_4[6] = 0.55^0.75^0.4^0.25=0.25

R_4=F_1[1]^F_2[1]^F_3[3]^F_4[6] = 0.55^0.25^0.6^0.25=0.25

R_5=F_1[1]^F_2[1]^F_3[2]^F_4[5] = 0.55^0.25^0.4^0.75=0.25

R_6=F_1[1]^F_2[2]^F_3[2]^F_4[5] = 0.55^0.75^0.25^0.75=0.25

R_7=F_1[1]^F_2[1]^F_3[2]^F_4[6] = 0.55^0.25^0.4^0.25=0.25

R_8=F_1[1]^F_2[2]^F_3[3]^F_4[6] = 0.55^0.75^0.6^0.25=0.25

R_9=F_1[2]^F_2[1]^F_3[2]^F_4[5] = 0.45^0.25^0.4^0.75=0.25

R_{10}=F_1[2]^F_2[1]^F_3[3]^F_4[5] = 0.45^0.25^0.6^0.75=0.25

R_{11}=F_1[2]^F_2[2]^F_3[2]^F_4[6] = 0.45^0.75^0.4^0.25=0.25

R_{12}=F_1[2]^F_2[2]^F_3[3]^F_4[6] = 0.45^0.75^0.4^0.25=0.25

R_{13}=F_1[2]^F_2[1]^F_3[2]^F_4[5] = 0.45^0.25^0.4^0.75=0.25

R1$_4$=F_1[2]^F_2[1]^F_3[3]^F_4[5] = 0.45^0.25^0.6^0.75=0.25

R_{15}=F_1[2]^F_2[2]^F_3[2]^F_4[6] = 0.45^0.75^0.4^0.25=0.25

R_{16}=F_1[2]^F_2[1]^F_3[3]^F_4[6] = 0.45^0.25^0.6^0.25=0.25

3.4.4 RULE SELECTOR

The rule base receives the four crisp values of inputs; volume, specific gravity, viscosity and chemical selection and gives the sixteen singleton values by applying the fuzzy if-then rules [42], as shown in figurer-3.41

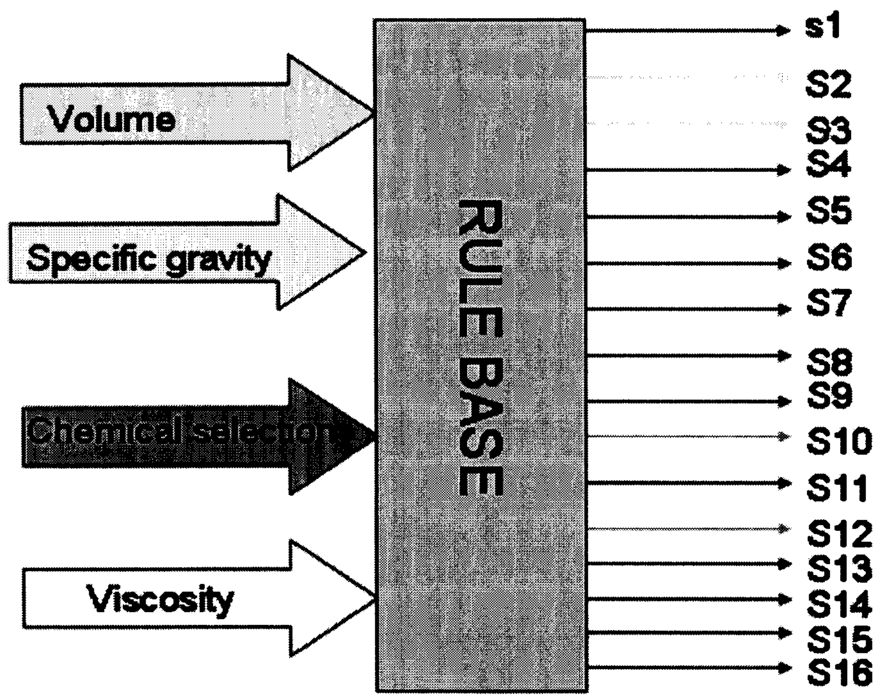


Figure-3.41 Design model of input and output of rule base for soap manufacturing system.

In the output membership functions plot there two overlapping regions and four inputs are used for system so total sixteen rules are required which are listed in table-3.29

Table-3.29 Design rules for soap manufacturing system

Volume	Viscosity	Specific Gravity	Chemical selected	Tem.	Tem. Time	Mixing Speed	Mixing Time	Valve	Valve opening time	PH	PH time
Very Small	High	Very Small	Small	Low	Long	Fast	Long	FEW	Long	Small	Long
Very small	Very High	Very Small	Small	Low	Medium	Fast	Medium	FEW	Medium	Small	Medium
Very small	High	Very Small	Medium	Low	Long	Medium	Long	FEW	Long	Small	Long
very Small	Very High	Very Small	Medium	Low	Medium	medium	medium	FEW	Medium	Small	Medium
Small	High	Very Small	Small	Low	Long	Fast	Long	FEW	Long	Small	Long
Small	Very High	Very Small	Small	Low	Medium	Fast	Medium	FEW	Medium	Small	Medium
Small	High	Very Small	Medium	Low	Long	Medium	Long	FEW	Long	Small	Long
Small	Very High	Very Small	Medium	Low	Medium	Medium	Medium	FEW	Medium	Small	Medium
Very Small	High	Small	Small	Low	Long	Fast	Long	Medium	Long	Small	Long
Very Small	Very High	Small	Small	Low	Medium	Fast	Medium	Medium	Medium	Small	Medium
Very Small	High	Small	Medium	Low	Long	Medium	Long	Medium	Long	Small	Long
very Small	Very High	Small	Medium	Low	Medium	Medium	Medium	Medium	Medium	Small	Medium
Small	High	Small	Small	Low	Long	Fast	Long	Medium	Long	Small	Long
Small	Very High	Small	Small	Low	Medium	Fast	Medium	Medium	Medium	Small	Medium
Small	High	Small	Medium	Low	Long	Medium	Long	Medium	Long	Small	Long
Small	Very High	Small	Medium	Low	Medium	Medium	Medium	Medium	Medium	Small	Medium

Singleton values obtained from knowledge base for applied rule are listed in table-3.30

Table-3.30 Singleton values for soap manufacturing system

Singleton Value	Tem.	Tem. Time	Mixing speed	Mixing Time	PH	PH time	valve	Valve Opening Time
S_1	0.3	0.7	0.7	0.7	0.3	0.7	0.3	0.7
S_2	0.3	0.5	0.7	0.5	0.3	0.5	0.3	0.5
S_3	0.3	0.7	0.5	0.7	0.3	0.7	0.3	0.7
S_4	0.3	0.5	0.5	0.5	0.3	0.5	0.3	0.5
S_5	0.3	0.7	0.7	0.7	0.3	0.7	0.3	0.7
S_6	0.3	0.5	0.7	0.5	0.3	0.5	0.3	0.5
S_7	0.3	0.7	0.5	0.7	0.3	0.7	0.3	0.7
S_8	0.3	0.5	0.5	0.5	0.3	0.5	0.3	0.5
S9	0.3	0.7	0.7	0.7	0.3	0.7	0.5	0.7
S10	0.3	0.5	0.7	0.5	0.3	0.5	0.5	0.5
S11	0.3	0.7	0.5	0.7	0.3	0.7	0.5	0.7
S12	0.3	0.5	0.5	0.5	0.3	0.5	0.5	0.5
S13	0.3	0.7	0.7	0.7	0.3	0.7	0.5	0.7
S14	0.3	0.5	0.7	0.5	0.3	0.5	0.5	0.5
S15	0.3	0.7	0.5	0.7	0.3	0.7	0.5	0.7
S16	0.3	0.5	0.5	0.5	0.3	0.5	0.5	0.5

Rule base block for the design model of soap manufacturing system contains lookup table, it consists of rules which are design for model. four comparators, four detectors and four decoders , these detectors and decoders tells about the region maps by the input variable and response of fuzzy set to these variable. Comparator takes information's from detectors and decoders and gives the singleton values. As shown in figure-3.42

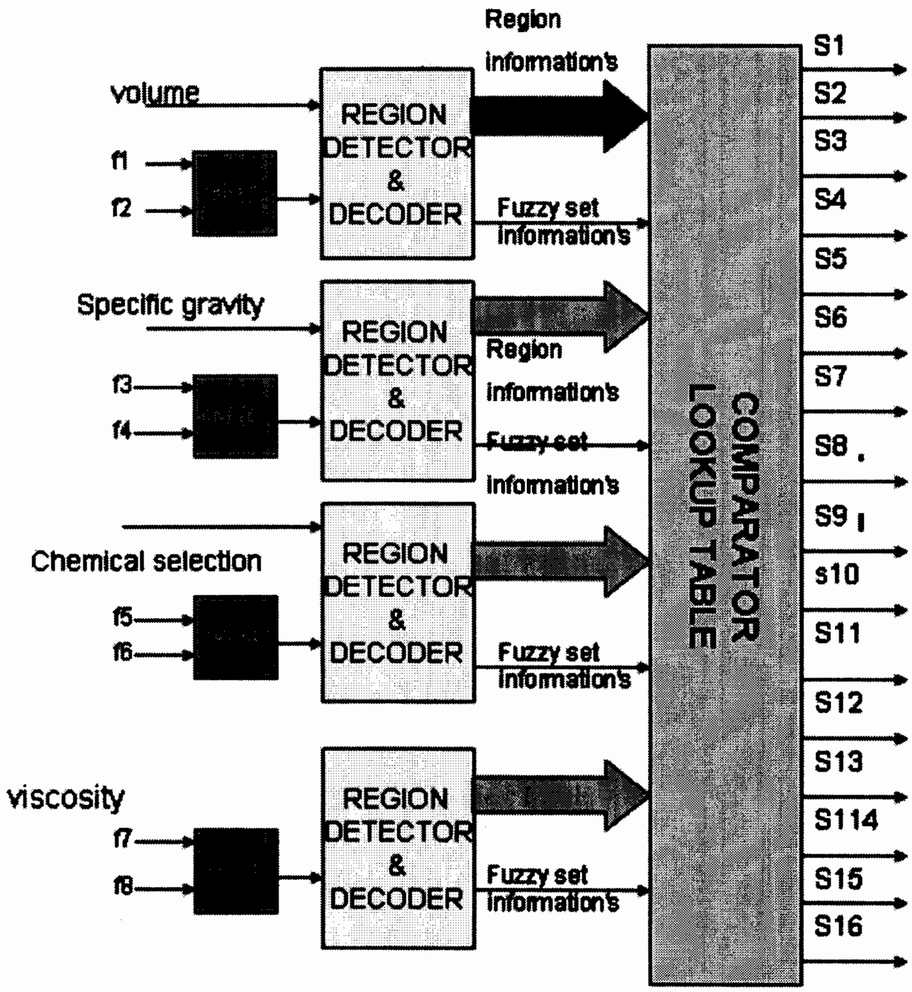


Figure-3.42 Arrangement of rule base to get singleton values for soap manufacturing system.

3.4.5 DEFUZZIFICATION.

The conversion of linguistic variables in to crisp/numeric values is known as defuzzification. The method used for defuzzification is (COA) center of average

Whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Where i =1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.

For the designed soap manufacturing system eight defuzzifiers are used, for eight output variables. This system takes thirty-two inputs to each defuzzifier sixteen from inference engine i.e. R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9 R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, $R_{15}$and R_{16} and sixteen from the rule base i.e. S_1, S_2, S_3, S_4 S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}, S_{13}, S_{14}, S_{15}, and S_{16} and gives the crisp value of output variables. As shown in figure-3.4

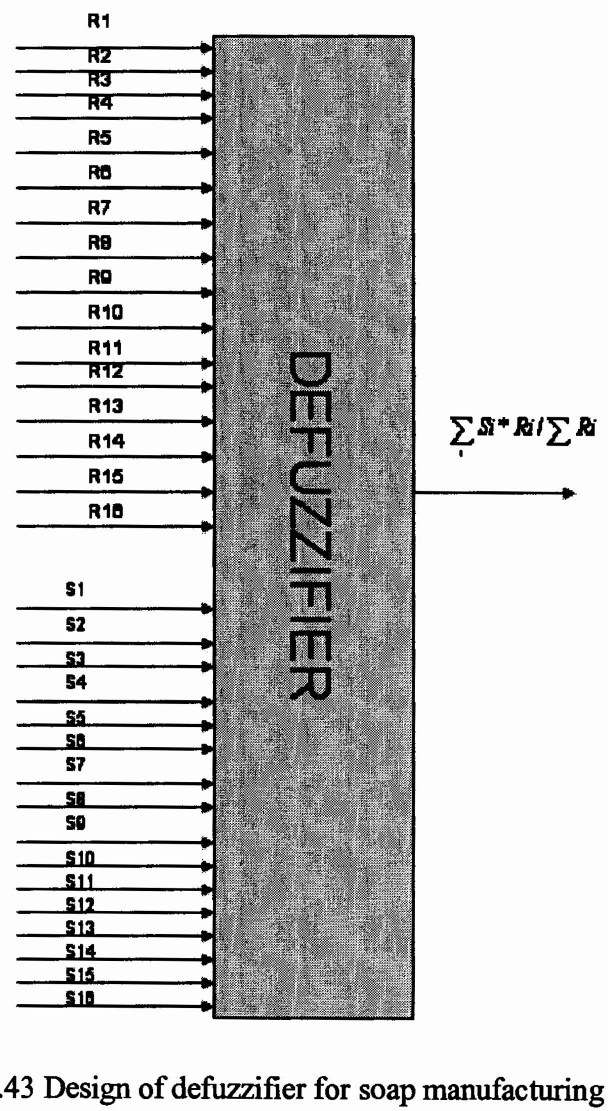


Figure-3.43 Design of defuzzifier for soap manufacturing system.

The modeling of defuzzifier is shown in the figure-3.44; one defuzzifier contains adder, multipliers and divider. For the soap manufacturing system we require sixteen multiplies, two adders and one divider to implement the COA method.

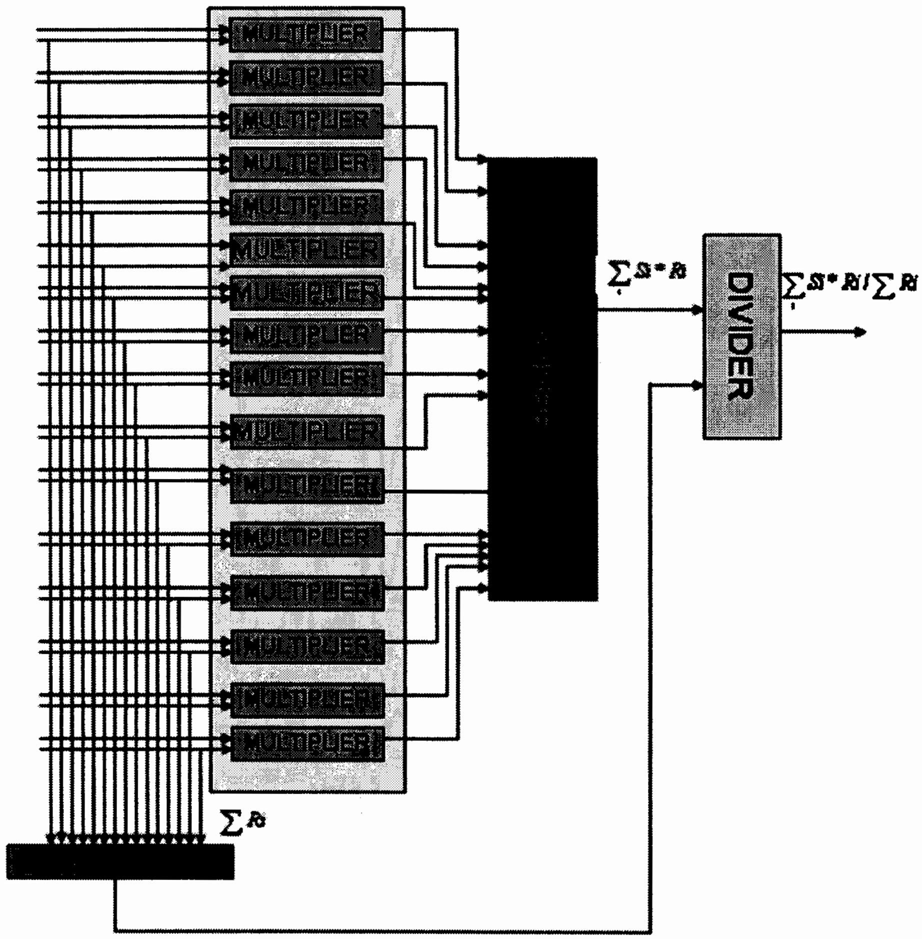


Figure-3.44 Design model of defuzzifier for soap manufacturing system.

3.4.6 EXPERIMENTAL ARRANGEMENT.

The experimental arrangements for the designed soap manufacturing system is shown in figure-3.45

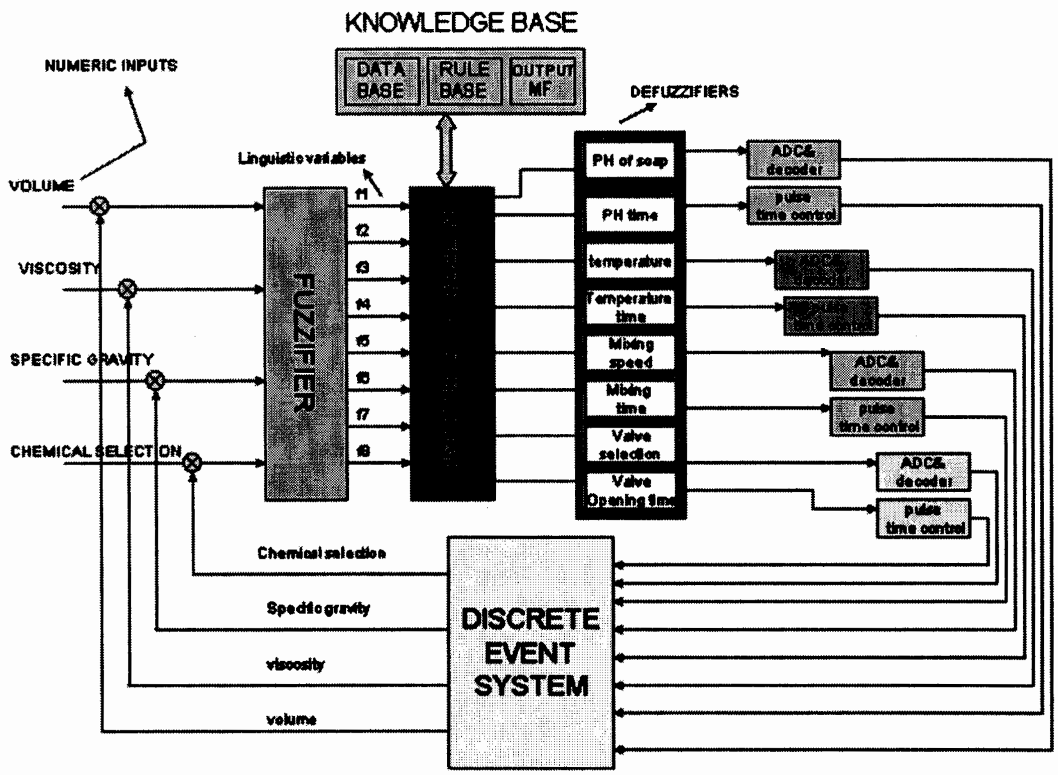


Figure-3.45 Experimental arrangement for soap manufacturing system.

CHAPTER-4

RESULT DISCUSSION AND CONCLUSION

4.1 AUTONOMOUS AIR CONDITIONING SYSTEM.

The autonomous air conditioning system is designed with two inputs: Temperature, and humidity, and two outputs: fan speed and fan spinning time. Temperature and humidity are controlled by controlling the three valves i.e. cooling valve, heating valve and humidifying valve. System takes feedback from sensors. Fuzzy time control rules are formed and simulated by using the MATLAB tool box.

4.1.1 EXPERIMENTAL ARRANGEMENT.

Autonomous air conditioning system contains two inputs; temperature and humidity, for these two inputs two fuzzifiers and two defuzzifiers are used. To verify the designed autonomous air conditioning system we use the input fuzzy variables temperature=22°c and humidity=30. Corresponding to these two inputs fuzzifier gives four outputs in the form of linguistic variables; these linguistic variables are then given to the inference engine which gives four values of R.

$$R_1=F\ [1] \text{ and } F\ [3] = 0.24 \text{ and } 0.2 = 0.2$$

$$R_2=F\ [1] \text{ and } F\ [4] = 0.24 \text{ and } 0.8 = 0.24$$

$$R_3=F\ [2] \text{ and } F\ [3] =0.76 \text{ and } 0.2 = 0.2$$

$$R_4=F\ [2] \text{ and } F\ [4] = 0.76 \text{ and } 0.8 = 0.76$$

For the designed model total twenty five rules are designed out of these twenty five rules four rules are used at a time which gives four singleton values; S1, S2, S3, and S4, these singleton values and four values of R, are given to the defuzzifiers which convert these linguistic values into crisp values using (C.O.A.) center of average method whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Here

i = 1, 2, 3, and 4.

4.1.2 MATLAB SIMULATION RESULTS.

MATLAB simulation results for autonomous air conditioning system exposed in figure-4.1. Simulation results show the whole fuzzy process and also describe how the membership functions effect on the overall results.

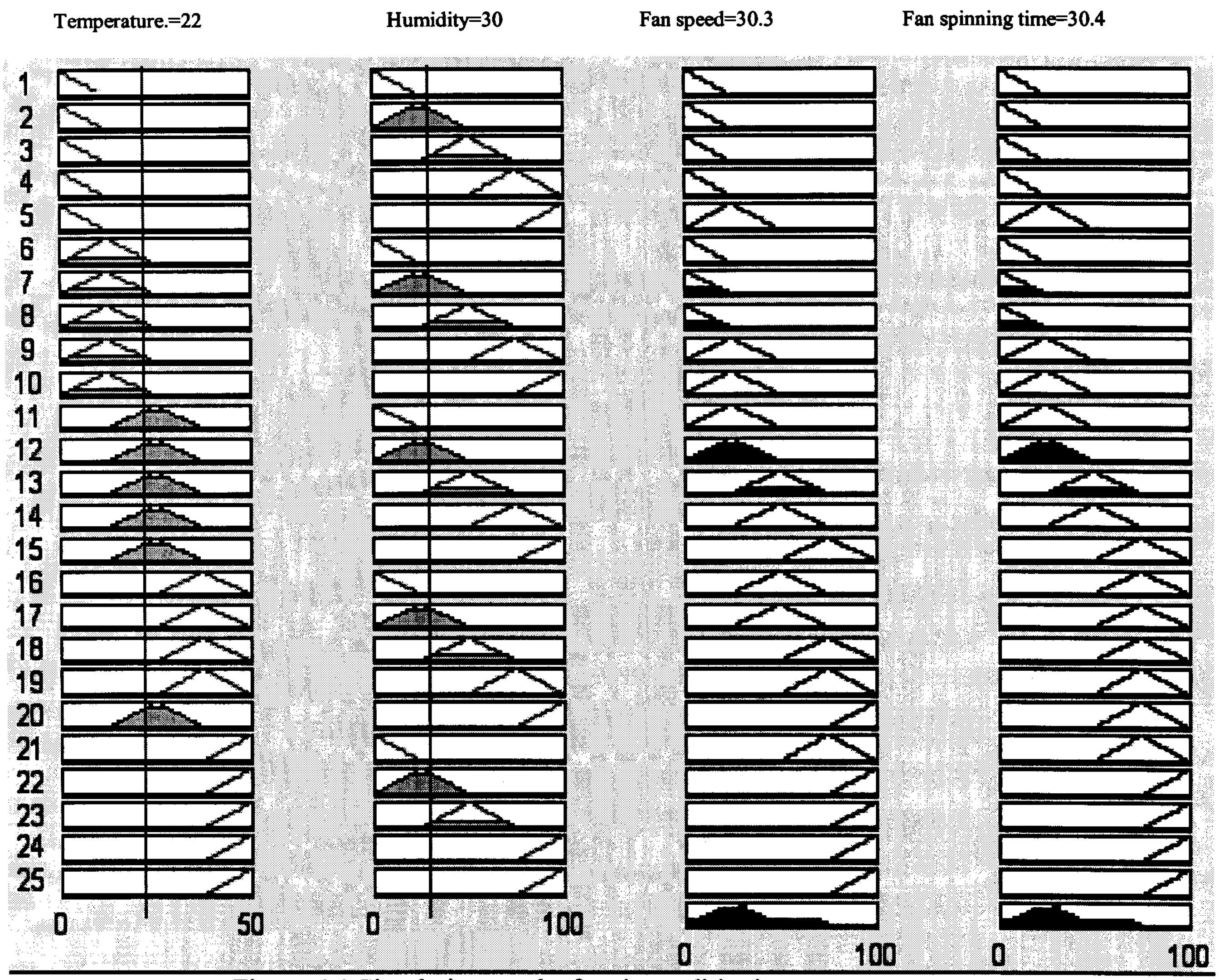


Figure-4.1 Simulation results for air conditioning system.

Output plot for MATLAB simulation results are exposed in figure-4.2(a) and figure-4.2(b). The figure-4.2(a) shows temperature and fan speed are directly proportional to each other and fan speed is independent of humidity up to the value of 50 and then gradually increased with humidity

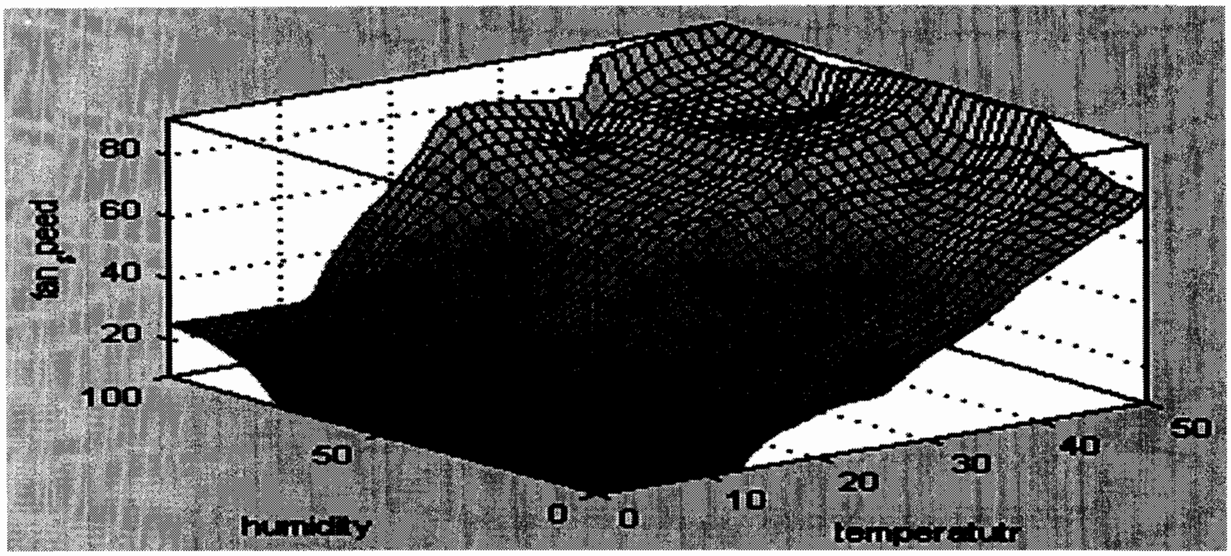


Figure-4.2 (a) Plot between humidity temperature and fan speed

Figure-4.2(b). Below shows that the temperature and fan spinning time are directly proportional to each other but humidity remains constant up to 50 and then increasedwith tim

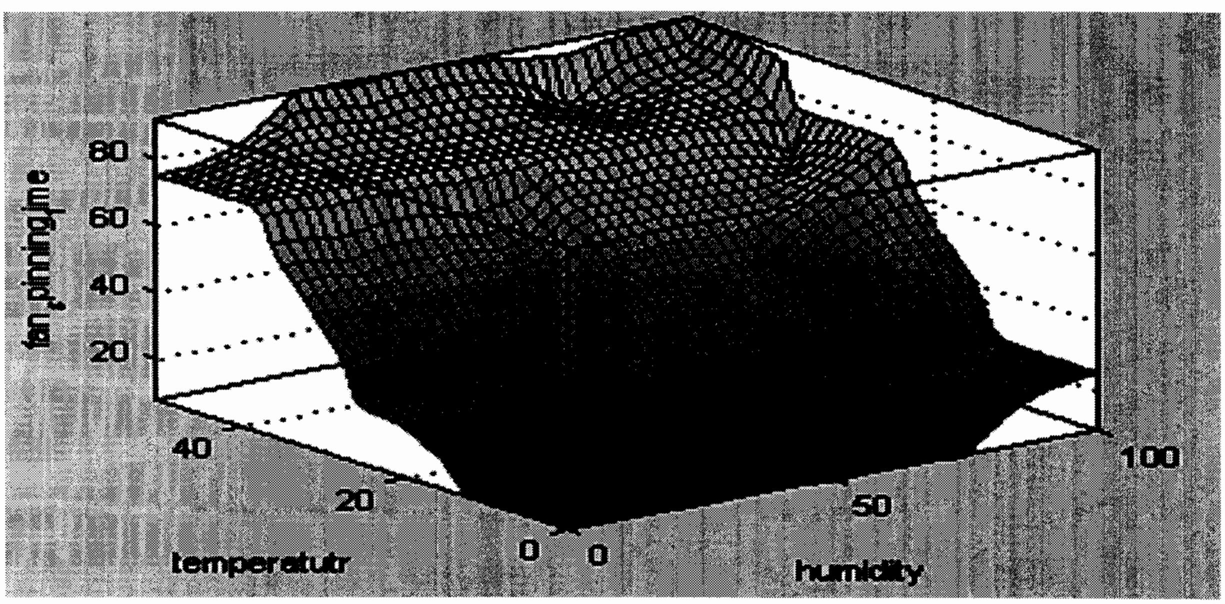


Figure-4.2(b) Plot between temperature, humidity and fan spinning time.

4.1.3 RESULTS OBTAINED FOR AIR CONDITIONING SYSTEM

MATLAB simulation results and the results obtained for design modeling corresponding to the input variables temperature= 22, humidity=30 are specified in table-4.1.

Table-4.1 Defuzzified values for autonomous air conditioning system.

	Fan speed	**Fan spinning time**
MATLAB simulation result	30.3	30.4
Manual calculated values	30	30

The error for both the values; fan speed, fan spinning time is approximately 1%

Which are quite satisfactory results and show the effectiveness of the approach.

4.1.4 CONCLUSION AND FUTURE WORK

This work presents the fuzzy time control discrete event model of autonomous air conditioning system and shows the effectiveness of the approach. Nowadays, the trend is to make systems, which use less energy, and give maximum efficiency. The proposed design fulfills these conditions and provides the conservation of energy due to its time dependency that operates the system for a specific period of time and gives the approximately same defuzzified values for MATLAB simulation and manual calculation. The system itself provides the base to design the other new systems using the technique of fuzzy time control discrete event systems in future.

4.2 SYRUP MANUFACTURING SYSTEM.

Pharmaceutical industries of world are manufacturing their most of the goods in syrup form. The proposed study relates with the designing of medicated syrup manufacturing by using the fuzzy time control discrete event system. The system is designed with three Inputs; viscosity, specific gravity and chemical selection and eight outputs; temperature, temperature time, mixing speed, mixing time, valve, valve opening time, PH at current liquid temperature and PH time. System is controlled by controlling the four parameters, valve selection, temperature monitoring unit, mixing motor and PH control unit. System takes feed back from four sensors time control rules are formulated and simulated by using MATLAB tool box

4.2.1 EXPERIMENTAL ARRANGEMENT.

Syrup manufacturing system contains three inputs; viscosity, specific gravity, and chemical selection for these three inputs three fuzzifiers and eight defuzzifiers are used. To verify the design model of syrup manufacturing the input fuzzy variable value are taken; viscosity=1.4, specific gravity=1.7 and chemical selection=16.

Corresponding to these three inputs fuzzifiers gives six outputs in the form of linguistic variables. Inference engine takes values from the Fuzzifier and applies min-composition and gives the eight values of R; R_1, R_2, R_3, R_4, R_5, R_6, R_7, and R_8.

$$R_1=F_1[3] \text{ and } F_2[3] \text{ and } F_3[3] = 0.4\wedge 0.3\wedge 0.4=0.3$$

$$R_2=F_1[2] \text{ and } F_2[3] \text{ and } F_3[3] = 0.6\wedge 0.3\wedge 0.4=0.3$$

$$R_3=F_1[3] \text{ and } F_2[2] \text{ and } F_3[3] = 0.4\wedge 0.7\wedge 0.4=0.4$$

$$R_4=F_1[2] \text{ and } F_2[2] \text{ and } F_3[3] = 0.6\wedge 0.7\wedge 0.4=0.4$$

$$R_5=F_1[3] \text{ and } F_2[3] \text{ and } F_3[2] = 0.4\wedge 0.3\wedge 0.6=0.3$$

R_6=F_1[2] and F_2[3] and F_3[2] = 0.6^0.3^0.6=0.3

R_7=F_1[3] and F_2[2] and F_3[2] = 0.4^0.7^0.6=0.4

R_8=F_1[2] and F_2[2] and F_3[2] = 0.6^0.7^0.6=0.6

For the designed model total eight rules are designed which give eight singleton values; S1, S2, S3, S4, S5, S6, S7 and S8 these singleton values and values of R, are given to the defuzzifieres which convert these linguistic values into crisp values using (C.O.A.) method whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Here

i = 1, 2, 3, 4, 5, 6, 7, and 8.

4.2.2 MATLAB SIMULATION RESULTS.

MATLAB simulation results for syrup manufacturing system are exposed in figure-4.3. Simulation results show the whole fuzzy process and also describe how the membership functions effect on the overall results.

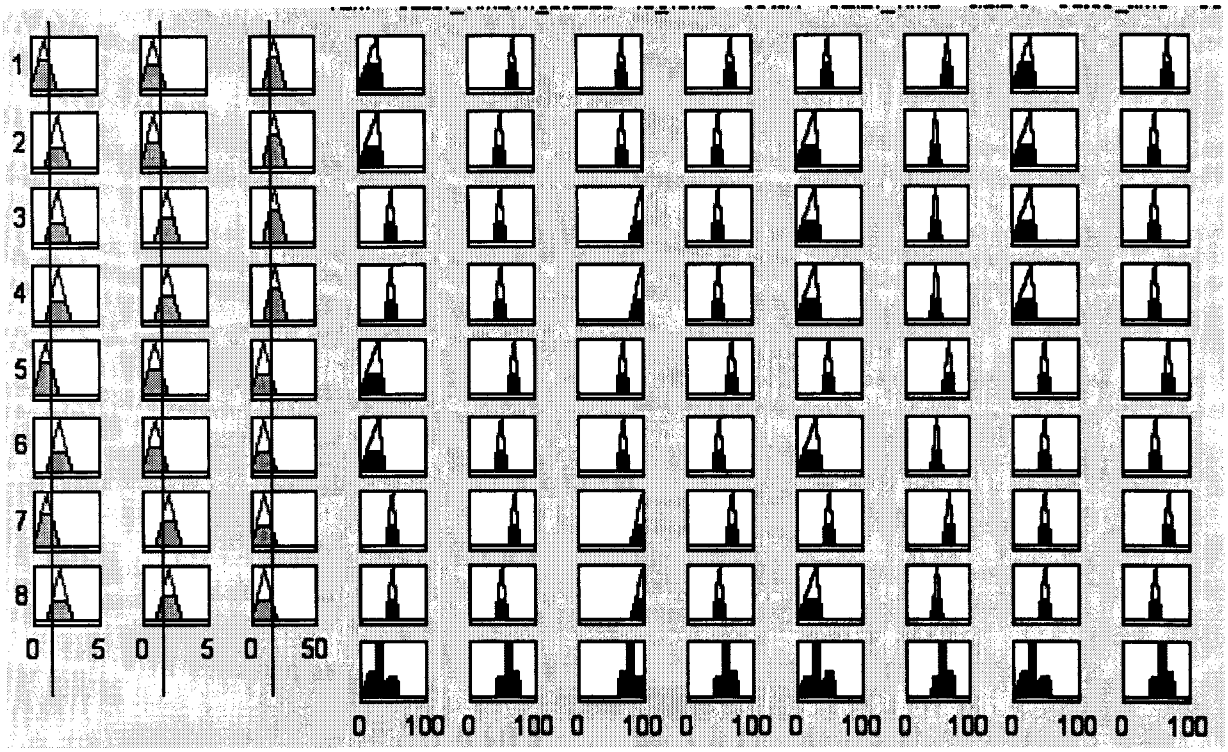


Figure-4.3 MATLAB simulation rule viewer

MATLAB simulation results for the proposed syrup manufacturing model are exposed in fig-4.4.(a to i)

Plot between temperature, viscosity and specific gravity exposed in Figure-4.4(a). plot shows temperature depends on viscosity and independent to specific gravity.

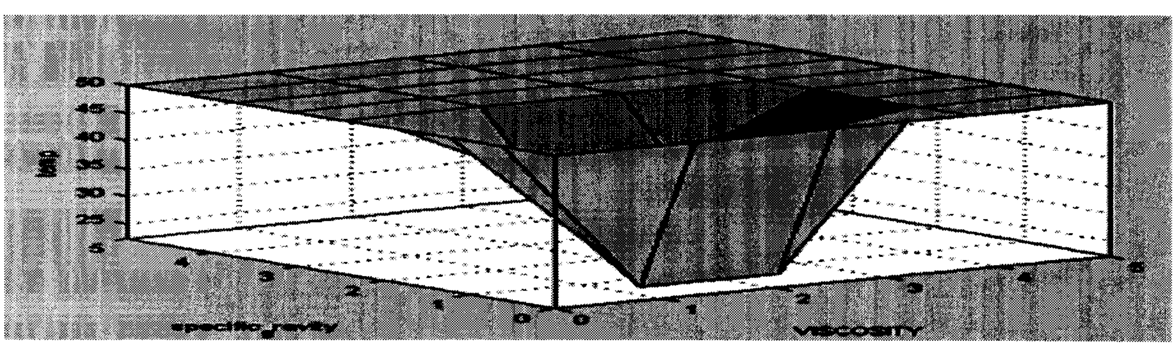


Figure-4.4(a) Plot between specific gravity viscosity and temperature for syrup manufacturing system.

Plot between specific gravity, viscosity and temperature time exposed in figure-4.4(b), plot shows cooling/ heating time is independent to specific gravity and depends on viscosity.

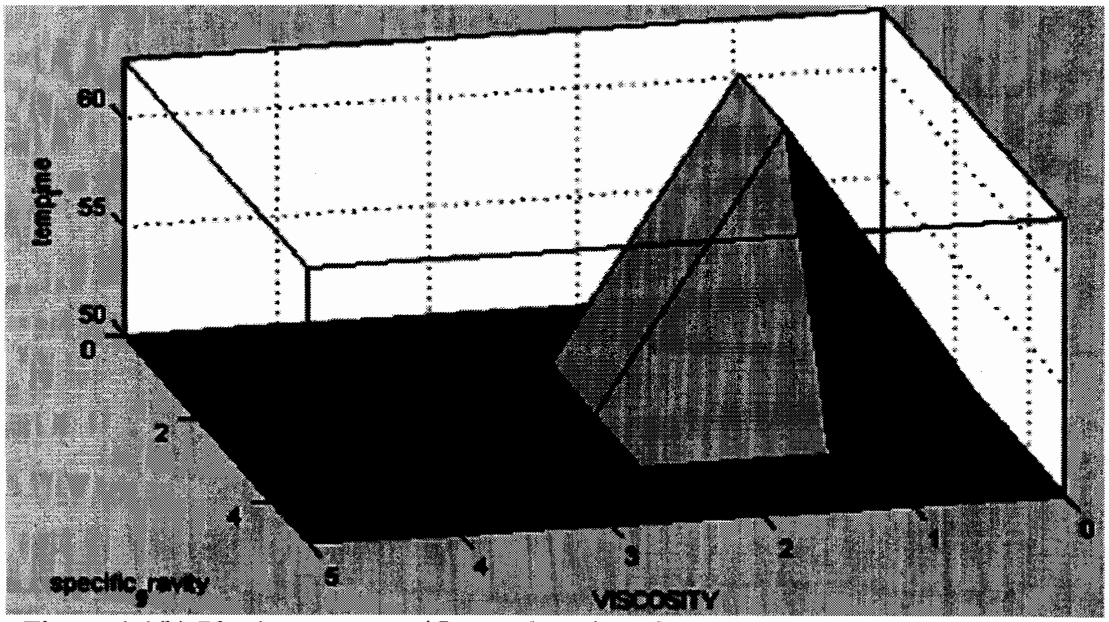


Figure-4.4(b) Plot between specific gravity, viscosity and temperature time for syrup manufacturing system.

Plot between viscosity, specific gravity and mixing speed exposed in Figure-4.4(c). Plot shows mixing speed does not depend on viscosity, it depends on specific gravity.

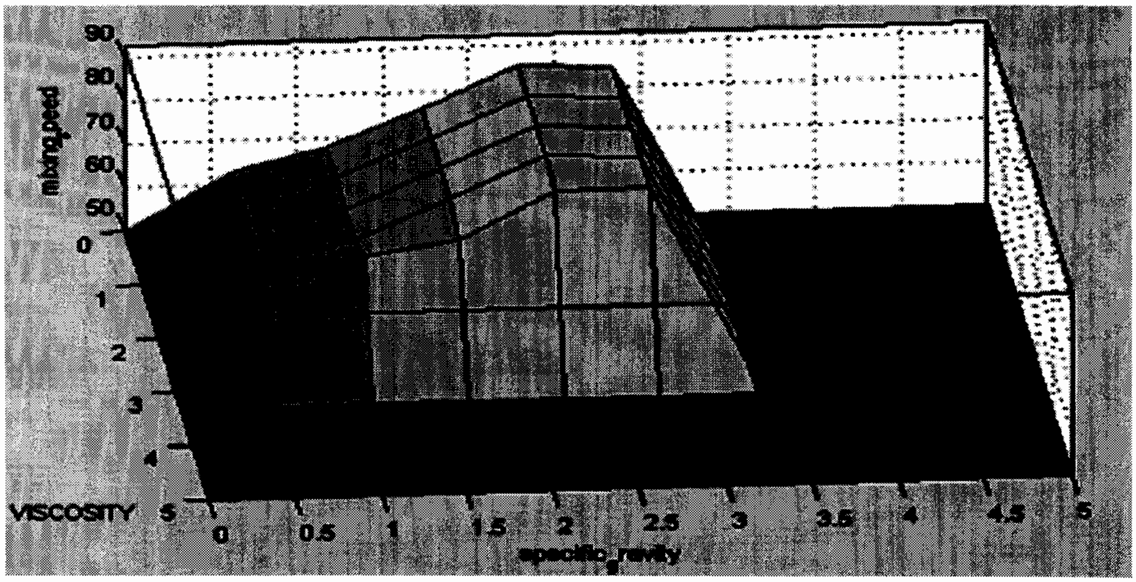


Figure-4.4(c) Plot between specific gravity, viscosity and mixing speed for syrup manufacturing system.

Plot between mixing time, viscosity and specific gravity exposed in Figure-4.4(d), plot shows rotating time depend on viscosity and independent to specific gravity.

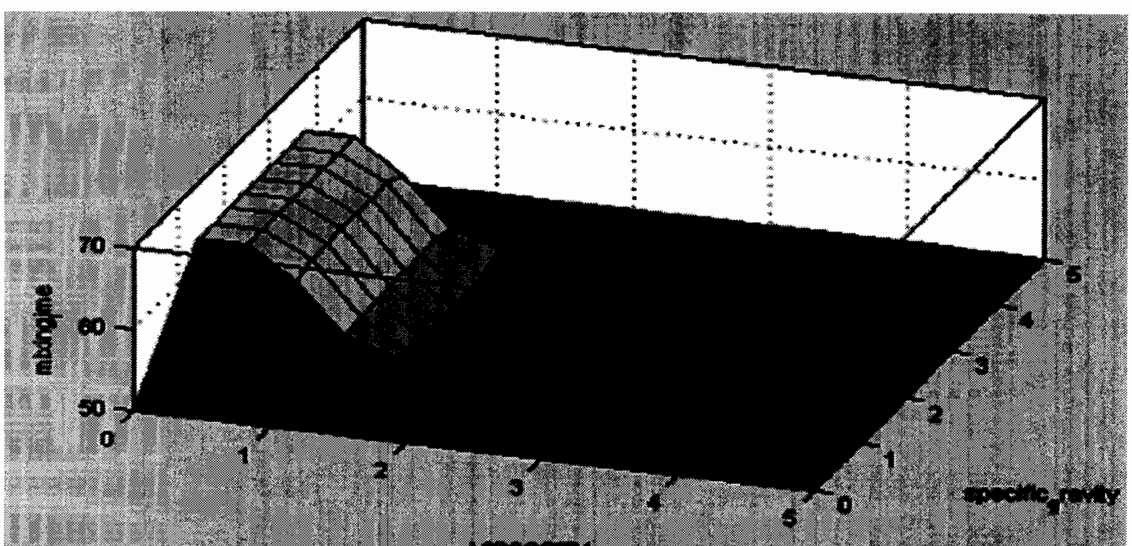


Figure-4.4(d) Plot between specific gravity, viscosity and mixing time for syrup manufacturing system.

Plot between valve selection, viscosity, and specific gravity exposed in Figure-4.4(e), which shows that valve opening is independent to viscosity of syrup it depends on specific gravity.

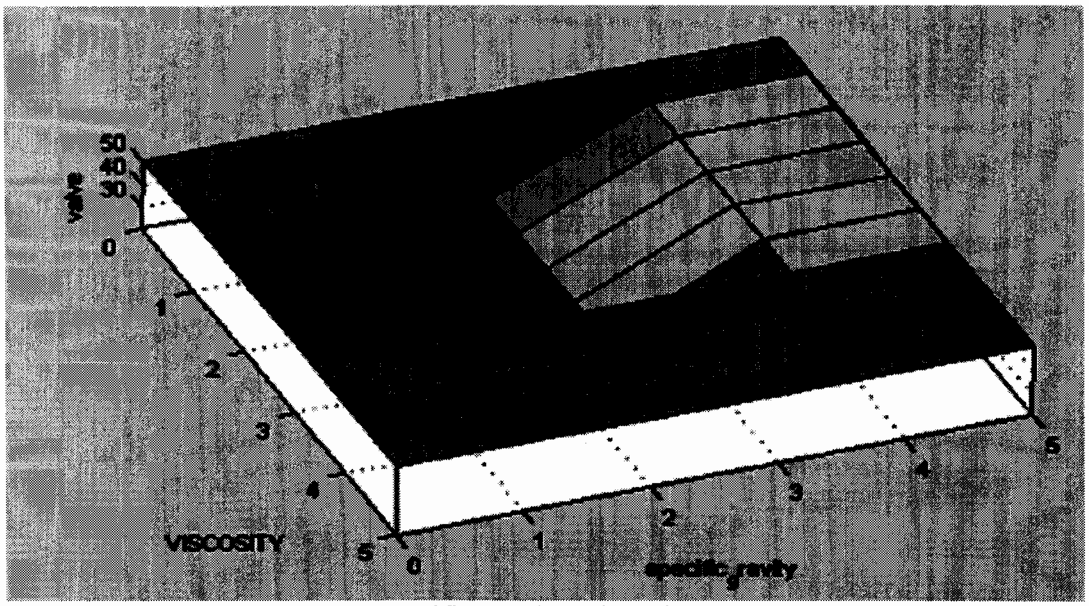


Figure-4.4(e) Plot between specific gravity, viscosity and valve opening for syrup manufacturing system.

Plot between viscosity, specific gravity, and PH of the syrup at current temperature exposed in Figure-4.4(f), plot shows PH is independent to viscosity and depends on specific gravity.

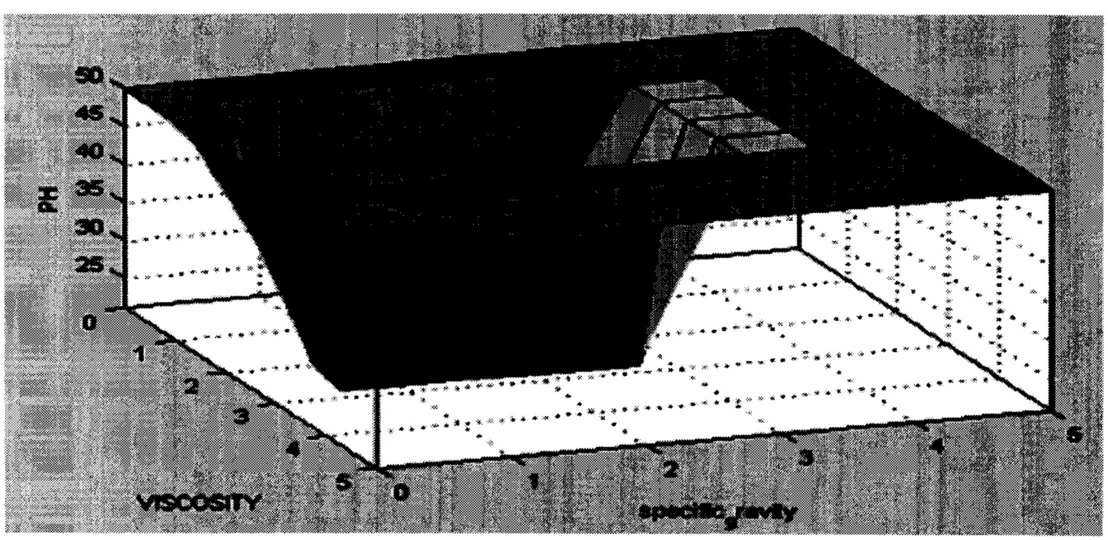


Figure-4.4(f) Plot between specific gravity, viscosity and the syrup PH for syrup manufacturing system.

Plot between viscosity, chemical selection and temperature exposed in Figure-4.4(g) plot shows temperature is independent to the viscosity and chemical selection.

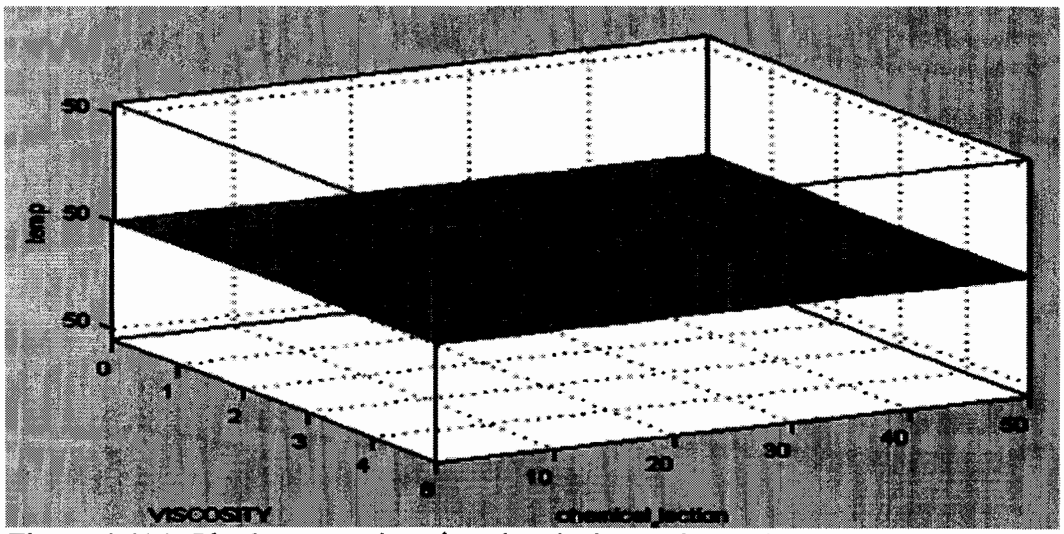


Figure-4.4(g) Plot between viscosity, chemical selection and temperature for syrup manufacturing system.

Plot between mixing speed, chemical selection and specific gravity exposed in

Figure-4.4(h), plot shows mixing speed depends on chemical selection and specific gravity.

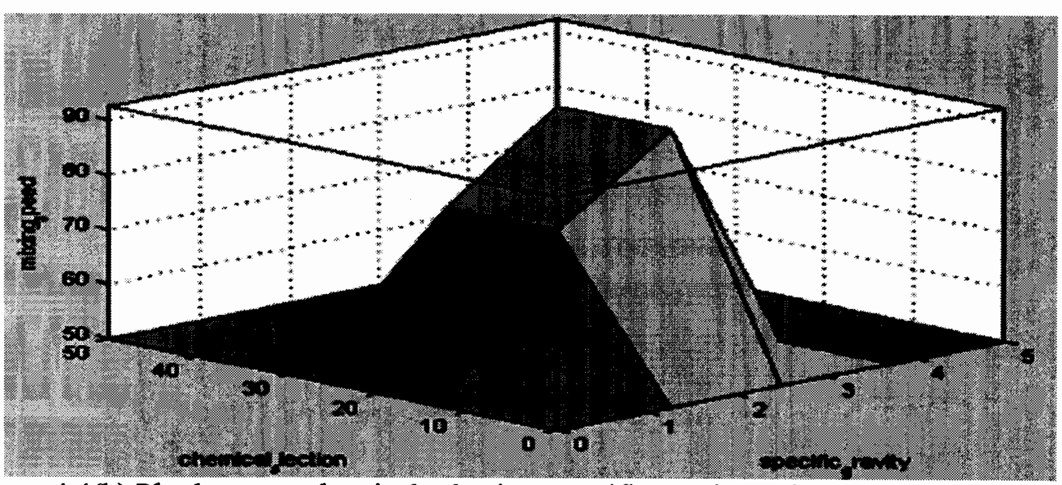
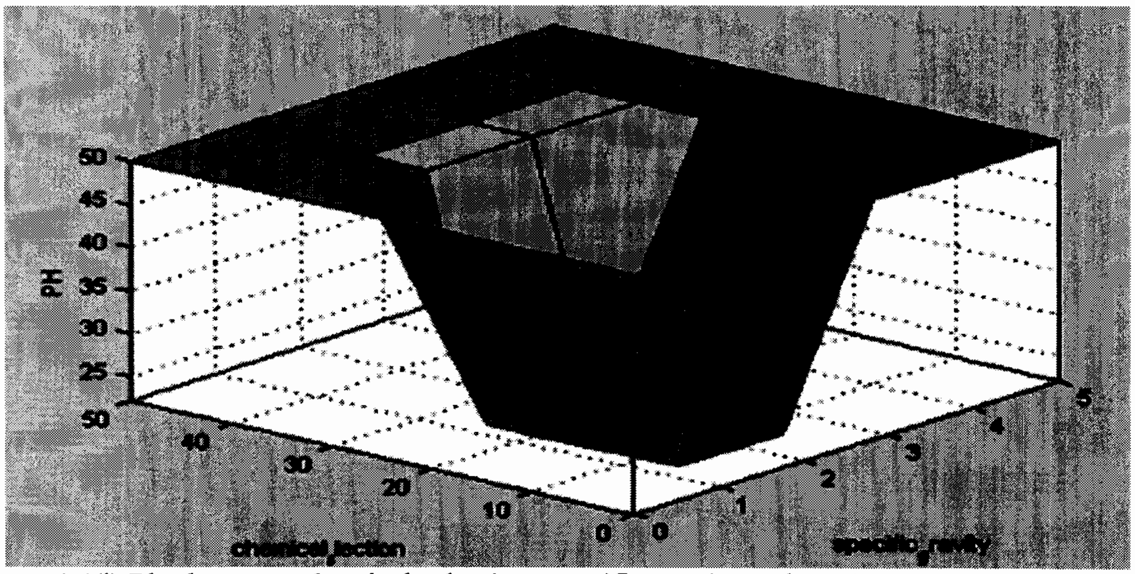


Figure-4.4(h) Plot between chemical selection, specific gravity and mixing speed for syrup manufacturing system.

Plot between PH, chemical selection, and specific gravity exposed in Figure-4.4(i), plot shows PH of syrup depends on specific gravity and independent to the chemical selection.



Figuge-4.4(i) Plot between chemical selection, specific gravity and PH for syrup manufacturing system.

4.2.3 RESULTS OBTAINED FOR SYRUP MANUFACTURING SYSTEM.

MATLAB simulation results obtained for the proposed syrup manufacturing system are exposed in above figure-4.4(a-i). It is clear from output plot that specific gravity and viscosity influence on the temperature, PH, and mixing speed, while the chemical selection effects on the valve selection.

Table-4.2 shows the output defuzzified values for temperature, temperature time, mixing speed, mixing time, valve, valve opening time, PH at current liquid temperature, PH time.

From MATLAB simulation and also the defuzzified values from manual calculation corresponding to the input variable viscosity=1.4' specific gravity=1.7 and chemical selected =16

Table-4.2 MATLAB simulation results for syrup manufacturing system.

	Tem.	Tem. time	Mixing Speed	Mixing Time	PH	PH Time	Valve	Valve Opening Time
MATLAB Simulation	40.3	61.4	84.4	61.4	34	61.4	31.1	61.4
Manual Calculated Values	42	59.8	86	59.8	36	59.8	34	59.8

The result obtained from MATLAB simulation and for designed model calculations are quite satisfactory and there is small error between them.

4.2.4 CONCLUSION AND FUTURE WORK

Proposed syrup manufacturing model is an industrial application of fuzzy time control discrete event system. Designed model is very efficient and simple in its performance and has flexibility to adjust the input and output parameters easily according to the syrup requirement. Design model provides the satisfactory defuzzified values from MATLAB simulation. Proposed syrup manufacturing model provides stable state of syrup in small interval of time.

4.3 ICE CREAM MANUFACTURING SYSTEM.

Ice cream is an important and very popular dairy product which is found in many flavors. With the development of the modern refrigeration system ice cream manufacturing has increased on large scale in industry [19-20]. The proposed Ice-cream manufacturing plant is designed to facilitate the ice cream manufacturing industry and provide a better and simple automated plant for manufacturing process. Proposed ice cream manufacturing plant is designed using two inputs; volume, and ingredient selection and six outputs; heating/cooling temperature,

temperature time, valve selection, valve opening time, mixing speed and mixing time, time control rules are formulated and simulated by using MATLAB tool box.

4.3.1 EXPERIMENTAL ARRANGEMENT.

Ice cream manufacturing system contains two inputs; volume and ingredient selection and six outputs; heating/cooling temperature, temperature time, valve selection, valve opening time, mixing speed and mixing time. In the proposed model two inputs two fuzzifiers and six defuzzifiers are used.

To verify the designed model of ice-cream manufacturing system the input fuzzy variables' values are taken; volume=28, ingredients selection=27. Corresponding to these two inputs fuzzifiers gives four outputs in the form of linguistic variables. Inference engine take values from the Fuzzifiers and apply min-max composition and gives the six values; R_1, R_2, R_3, R_4, R_5, R_6.

R_1=F [1] and F [3] = 0.4 and 0.3 = 0.3

R_2=F [1] and F [4] = 0.4 and 0.7 = 0.4

R_3=F [2] and F [3] = 0.6 and 0.3 = 0.3

R_4=F [2] and F [4] = 0.6 and 0.7 = 0.6

R_5=F [3] and F [4] = 0.3 and 0.7 = 0.3

R_6=F [1] and F [2] = 0.6 and 0.4 = 0.4

For the designed model total nine rules are designed which gives six singleton values; S1, S2, S3, S4, S5 and S6 these singleton values and values of R, are given to the defuzzifiers which convert these linguistic values into crisp values using (C.O.A.) method whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Here i = 1, 2, 3, 4, 5, and 6.

4.3.2 MATLAB SIMULATION RESULTS.

MATLAB simulation results for ice cream manufacturing system exposed in figure-4.5. Simulation results show the whole fuzzy process and also describe how the membership functions effect on the overall results.

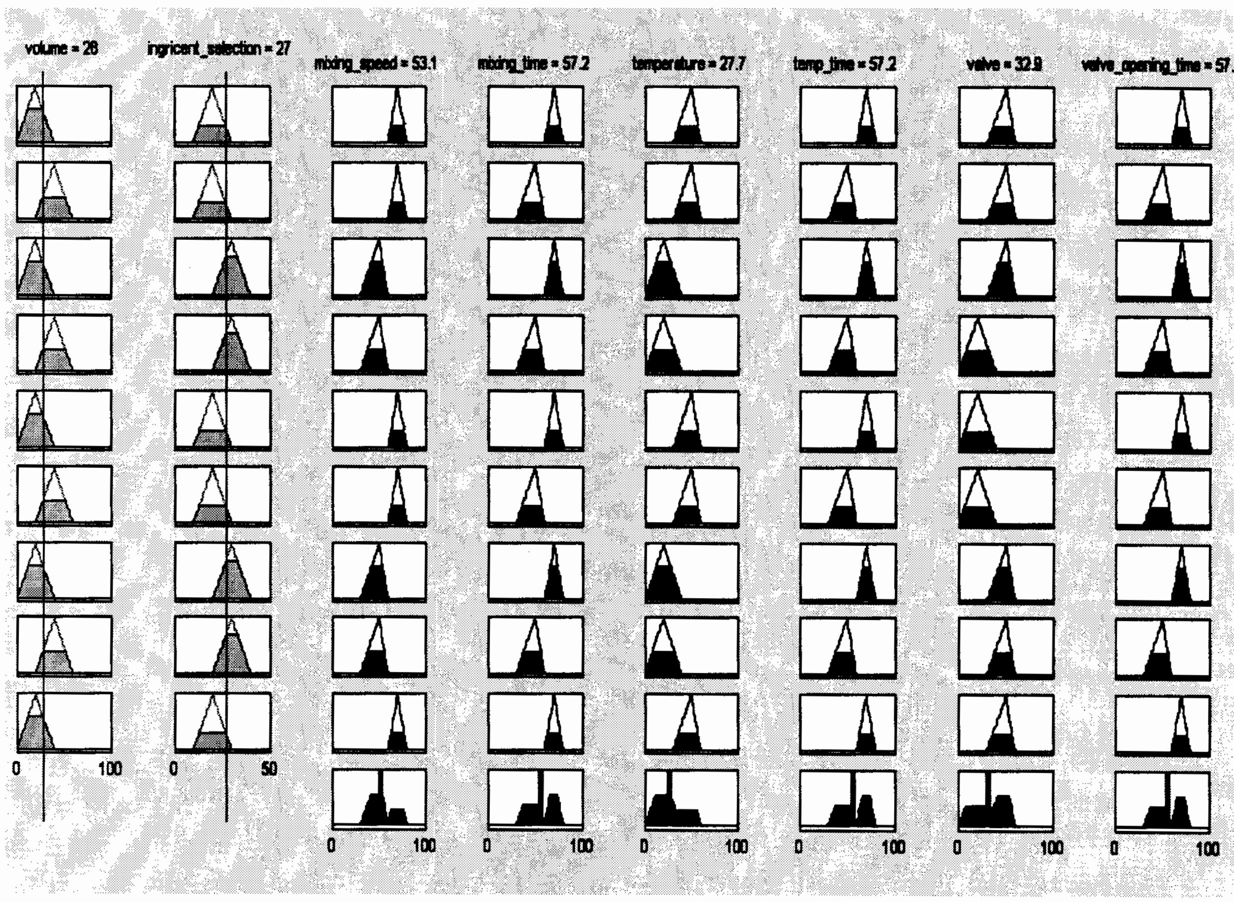


Figure-4.5 Shows the MATLAB rule viewer for ice cream manufacturing system.

MATLAB simulation results for the proposed syrup manufacturing model are shown in figure-.(a toi)

Plot between ingredient selection, volume and mixing speed exposed in Figure-4.6(a). Plot shows mixing speed depends on volume and independent to ingredient selection.

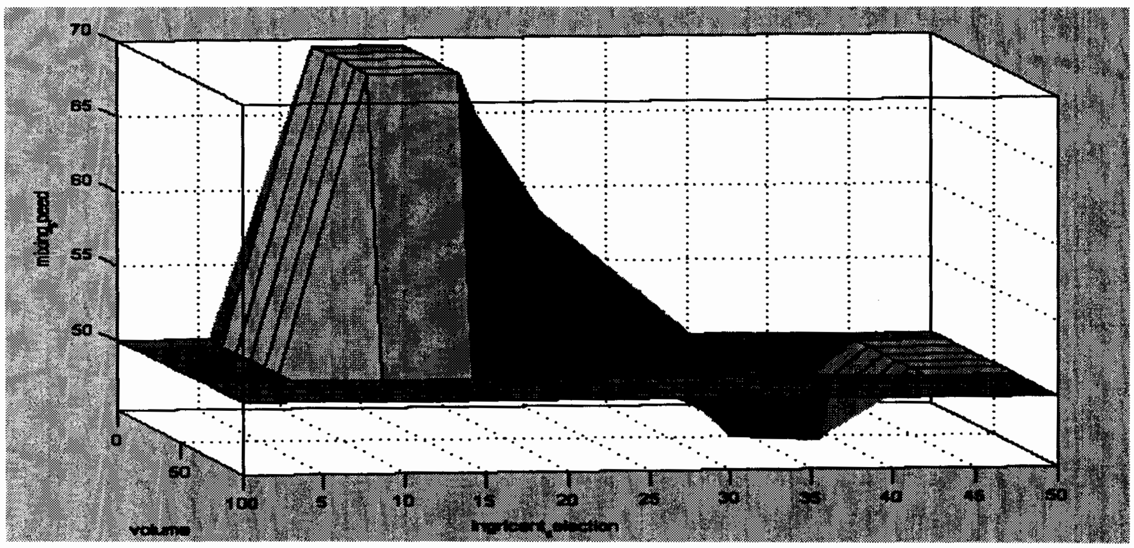


Figure-4.6(a) Plot between mixing speed, volume and ingredient selection for ice cream manufacturing system.

Plot between volume, ingredient selection and mixing time exposed in figure-4.6(b). Plot shows mixing time depends on volume and independent to the ingredient selection.

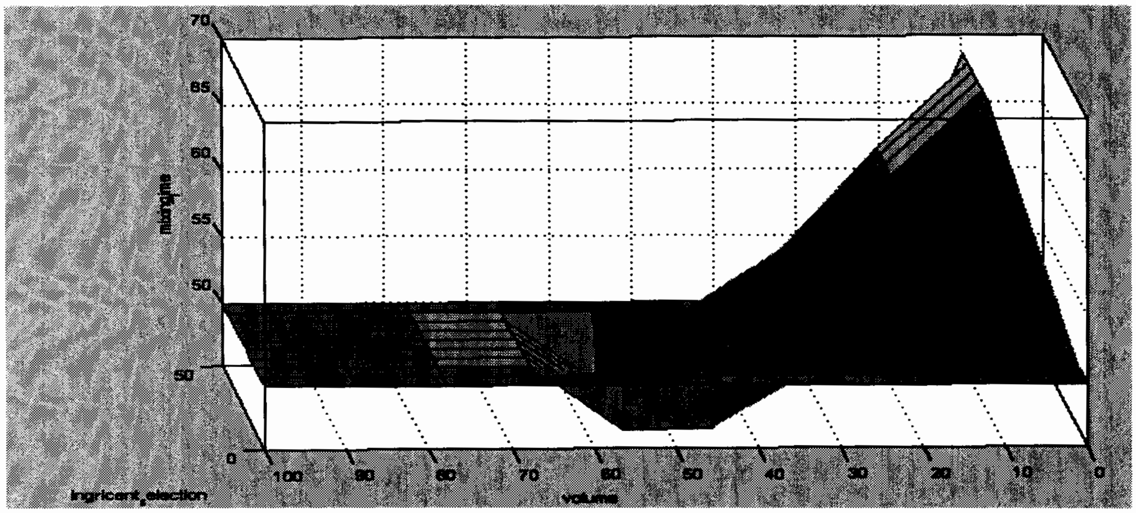


Figure-4.6(b) Plot between mixing time, volume and ingredient selection for ice cream manufacturing system.

Plot between heating/cooling temperature, volume and ingredient selection exposed in figure-4.6(c). Plot shows heating/cooling temperature depends on ingredient selection and independent to the volume.

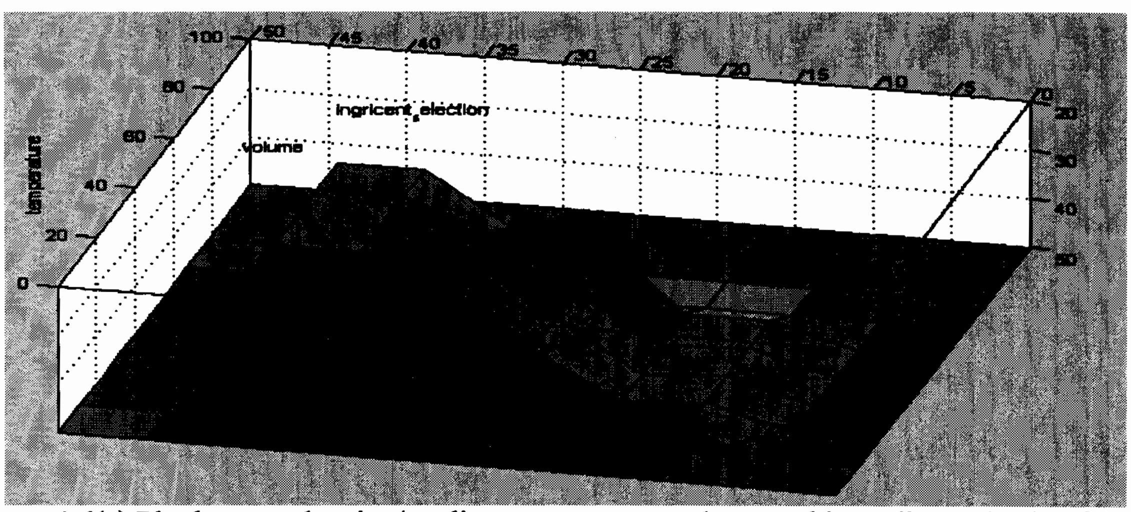


Figure-4.6(c) Plot between heating/cooling temperature, volume and ingredient selection for ice cream manufacturing system.

Plot between temperature time, volume and ingredient selection exposed in figure-4.6(d). Plot shows, temperature time depends on volume and independent to the ingredient selection.

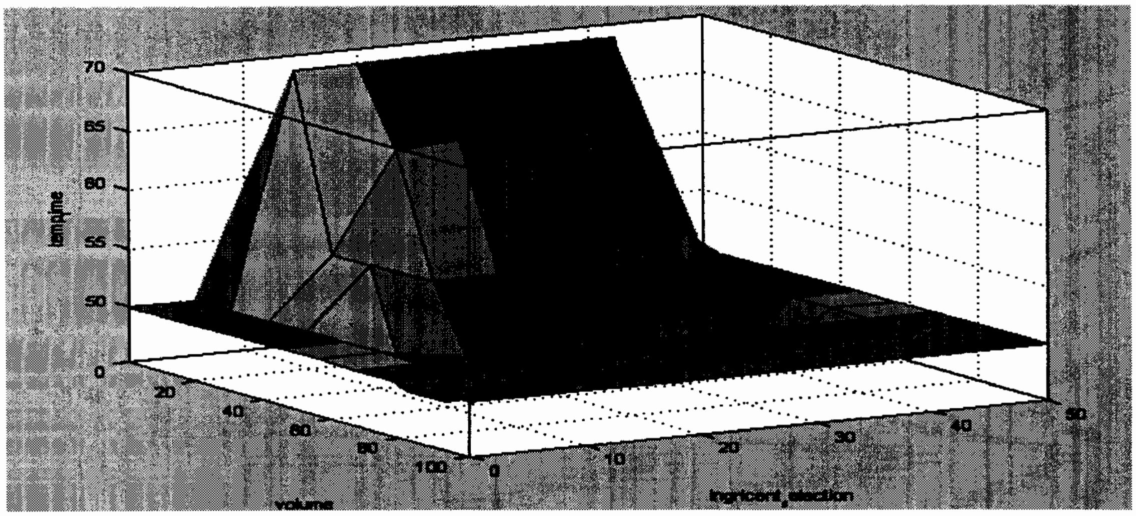


Figure-4.6(d) Plot between temperature time, volume and ingredient selection for ice cream manufacturing system.

Plot between valve selection, ingredient selection and volume exposed in figure-4.6(e). Plot shows, valve selection depends on the ingredient selection and independent to the volume.

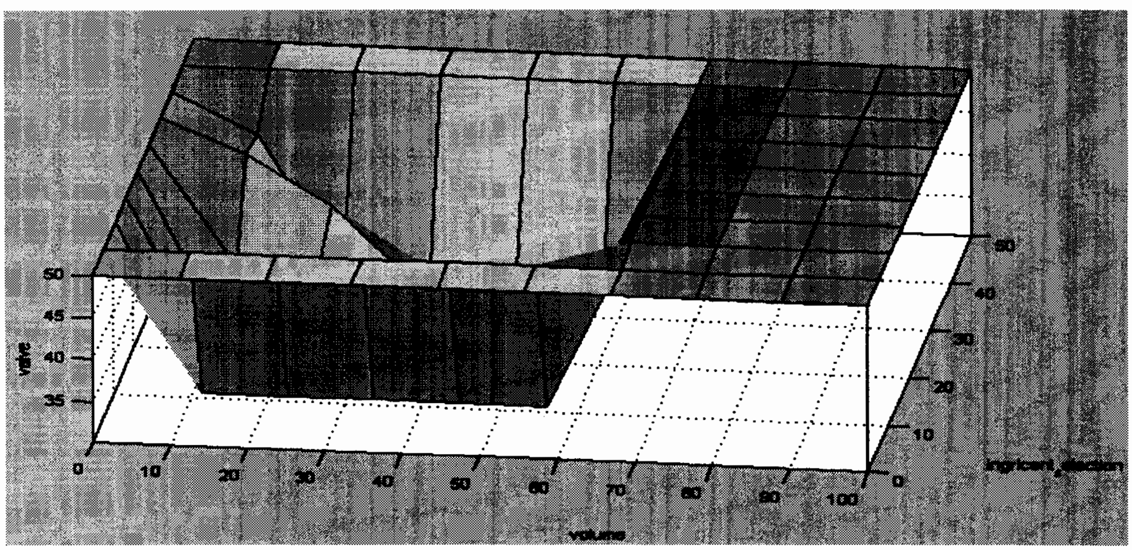


Figure-4.6(e) Plot between valve selection, ingredient selection and volume for ice cream manufacturing system.

Plot between valve opening time, volume and ingredient selection exposed in figure-4.6(f). Plot shows, valve opening time depends on volume and independent to the ingredient selection.

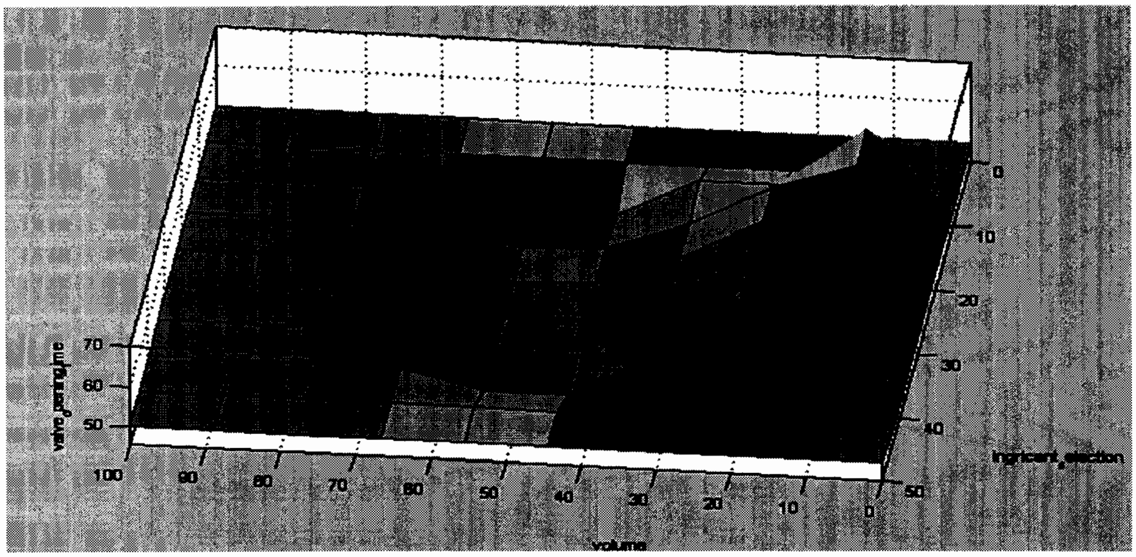


Figure-4.6(f) Plot between valve opening time, volume and ingredient selection for ice cream manufacturing system.

4.3.3 RESULTS OBTAINED FOR ICE CREAM MANUFACTURING SYSTEM.

MATLAB simulation results obtained for the proposed ice-cream manufacturing system exposed in above figure-4.6(a-f). It is clear from output plot that volume influence on the heating/cooling temperature time, mixing time and valve opening time. While the ingredient selection effect on the valve selection.

Table-4.3 shows the output defuzzified values for heating/cooling temperature, temperature time, mixing speed, mixing time, valve, valve opening time.

From MATLAB simulation and also the defuzzified values from manual calculation corresponding to the input variable volume=28 and ingredient selected =27

Table-4.3 MATLAB simulation results for ice cream manufacturing system.

	Tem.	Tem. time	Mixing Speed	Mixing time	valve	Valve Opening Time
MATLAB Simulation	27.7	57.2	53.1	57.2	32.9	57.2
Manual Calculated Values	28.2	57.8	55	57.8	34	57.8

The result obtained from MATLAB simulation and for designed model calculations are quite satisfactory and there is small error between them.

4.3.4 CONCLUSION AND FUTURE WORK

Proposed ice-cream manufacturing model is designed for industrial applications, using fuzzy time control discrete event system. Design system is very efficient and simple in their performance and has flexibility to adjust the input and output parameters easily according to the requirement. Design model provides the satisfactory Defuzzified values from MATLAB simulation.

4.4 SOAP MANUFACTURING SYSTEM.

Soap is an important anionic detergent which is frequently used in homes for bating, washing and many other ways in every day life [21-22]. Soap comes in many different shapes and forms like liquid, powder and solid bar. The soap solutions are characterized by parameters temperature, specific gravity, PH, viscosity, volume and viscous consistency. The proposed soap manufacturing model is designed using fuzzy time control discrete event system in which four inputs; volume, viscosity, specific gravity and chemical selection and eight outputs; heating/cooling temperature, temperature time, valve selection, valve opening time, PH, PH time, mixing speed and mixing time are used. The output variables of the system are time dependent and discussed with non probabilistic uncertainty issues [7] and controller work on heuristic knowledge [8] controller operate the plant ON or OFF for a specific period of time. System takes feed back from four sensors time control rules are formulated and simulated by using MATLAB tool box.

4.4.1 EXPERIMENTAL ARRANGEMENT.

Soap manufacturing system contains four inputs; viscosity, specific gravity, volume and chemical selection. To verify the design model of soap manufacturing the input fuzzy variable value are taken; viscosity=850, specific gravity=1.4, volume=10 and chemical selection=14.

Corresponding to these four inputs values fuzzifiers gives eight outputs in the form of linguistic variables. Inference engine takes its input values from the Fuzzifiers and gives sixteen values of R i.e. R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, and R_{16}.

R_1=F_1[1] and F_2[1] and F_3[2] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_2=F_1[1] and F_2[2] and F_3[3] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_3=F_1[1] and F_2[2] and F_3[2] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_4=F_1[1] and F_2[1] and F_3[3] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_5=F_1[1] and F_2[1] and F_3[2] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_6=F_1[1] and F_2[2] and F_3[3] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_7=F_1[1] andF_2[1] and F_3[2] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_8=F_1[1] and F_2[2] and F_3[3] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_9=F_1[2] and F_2[1] and F_3[2] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_{10}=F_1[2] and F_2[1] and F_3[3] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_{11}=F_1[2] and F_2[2] and F_3[2]and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_{12}=F_1[2] and F_2[2] and F_3[3] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_{13}=F_1[2] and F_2[1] and F_3[2] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R1_4=F_1[2] and F_2[1] and F_3[3] and F_4[5] = 0.6^0.7^0.4^.5=0.4

R_{15}=F_1[2] and F_2[2] and F_3[2] and F_4[6] = 0.6^0.7^0.4^.5=0.4

R_{16}=F_1[2] and F_2[1] and F_3[3] and F_4[6] = 0.6^0.7^0.4^.5=0.4

Here sign (^/and) represent the minimum and operation.

For the designed model total sixteen rules are designed which give sixteen singleton values; S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15 and S16 these singleton values and values of R, R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8 R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, R_{16}, are given to the defuzzifiers which convert these linguistic values into crisp values using COA method whose mathematical form is

$$\sum_i Si * Ri / \sum Ri$$

Here

i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16.

4.4.2 MATLAB SIMULATION RESULTS.

MATLAB simulation results for soap manufacturing system exposed in the figure-4.7. Simulation results show the whole fuzzy process and also describe how the membership functions effect on the overall results.

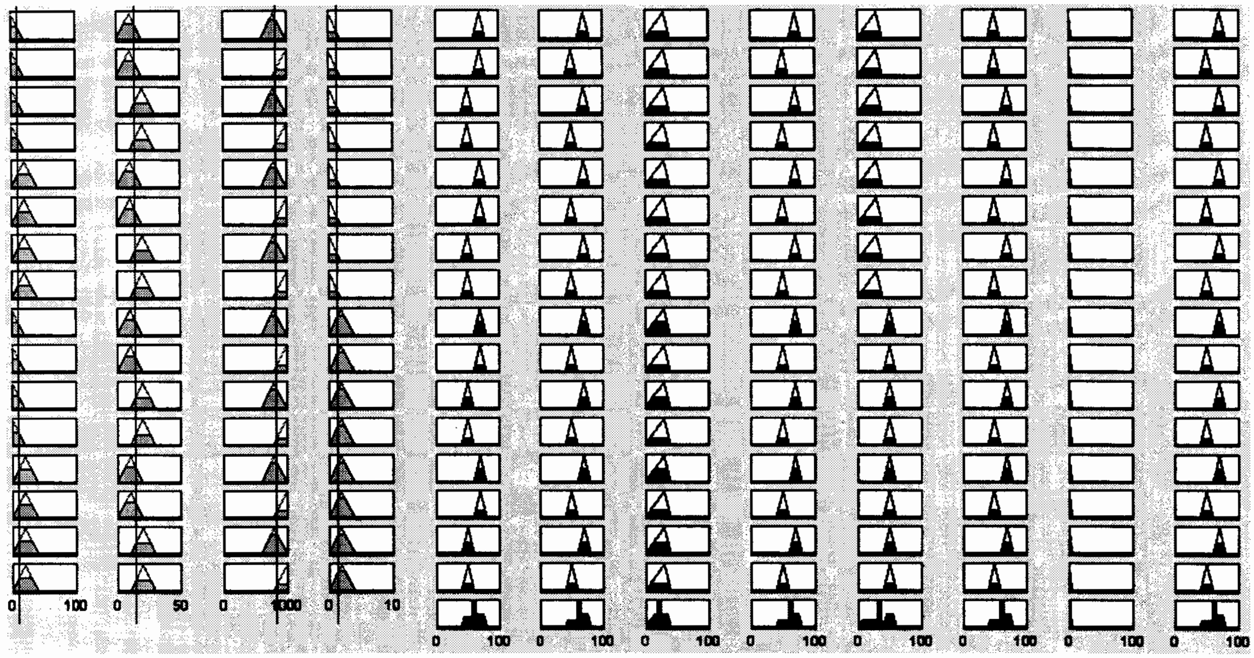


Figure-4.7 MATLAB simulation rule viewer for soap manufacturing system.

MATLAB simulation results for the proposed soap manufacturing model exposed in figure-4.8.(a toi)

Plot between temperature, volume and specific gravity exposed in Figure-4.8(a). Plot shows temperature depends on volume and independent to the specific gravity of the soap mixture.

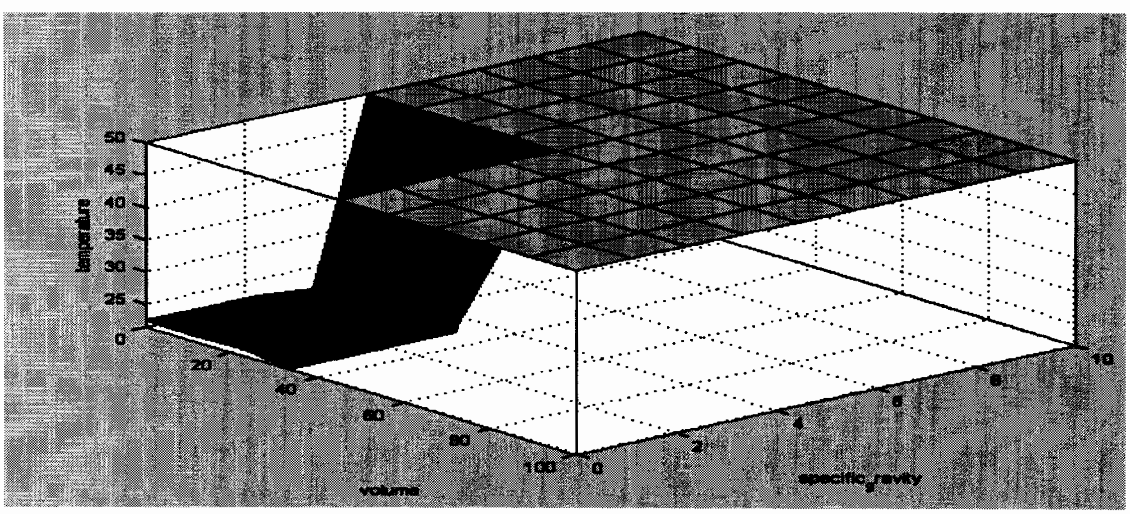


Figure-4.8(a) Plot between specific gravity, volume and temperature for soap manufacturing system.

Plot between specific gravity, volume and temperature time exposed in figure-4.8(b), plot shows cooling/ heating time does not depend on specific gravity it depend on the volume.

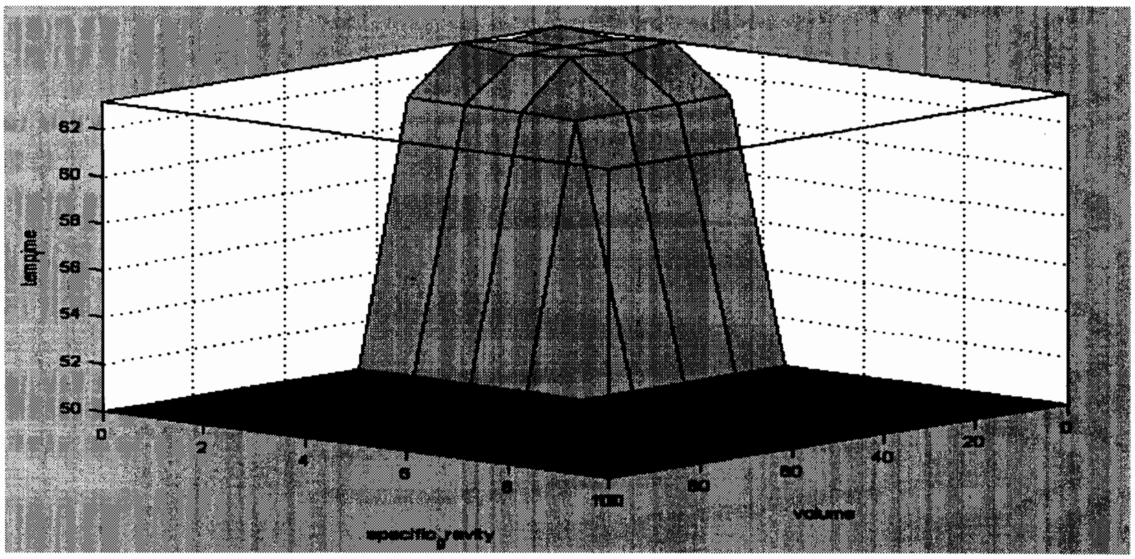


Figure-4.8(b) Plot between specific gravity, volume and temperature time for soap manufacturing system.

Plot between volume, specific gravity and mixing speed exposed in Figure-4.8(c), plot shows mixing speed does not depend on volume, it depends on specific gravity.

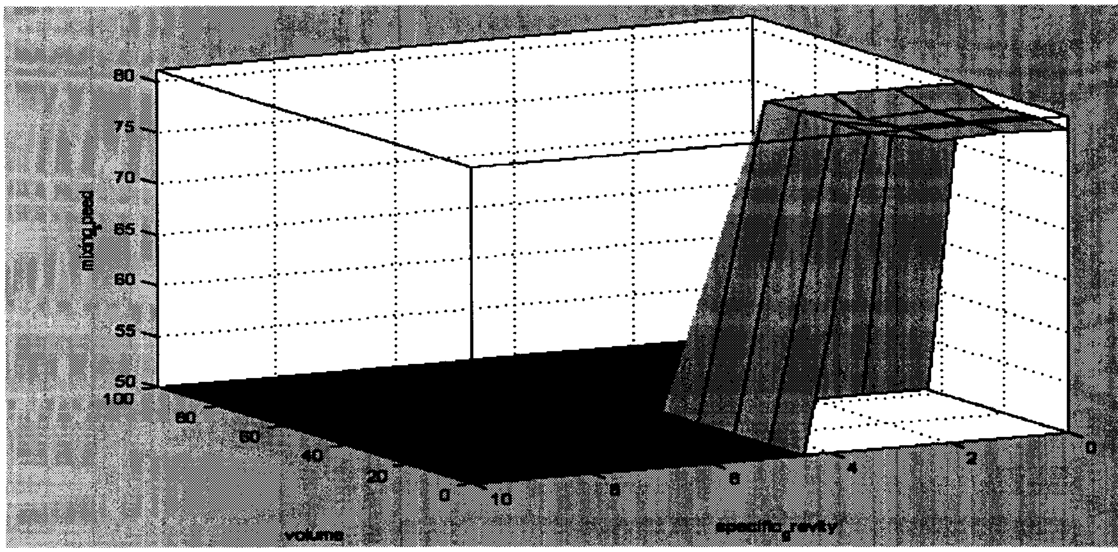


Figure-4.8(c) Plot between specific gravity, volume and mixing speed for soap manufacturing system.

Plot between PH, volume and specific gravity exposed in Figure-4.8(d), plot shows PH depend on volume it does not depend on specific gravity.

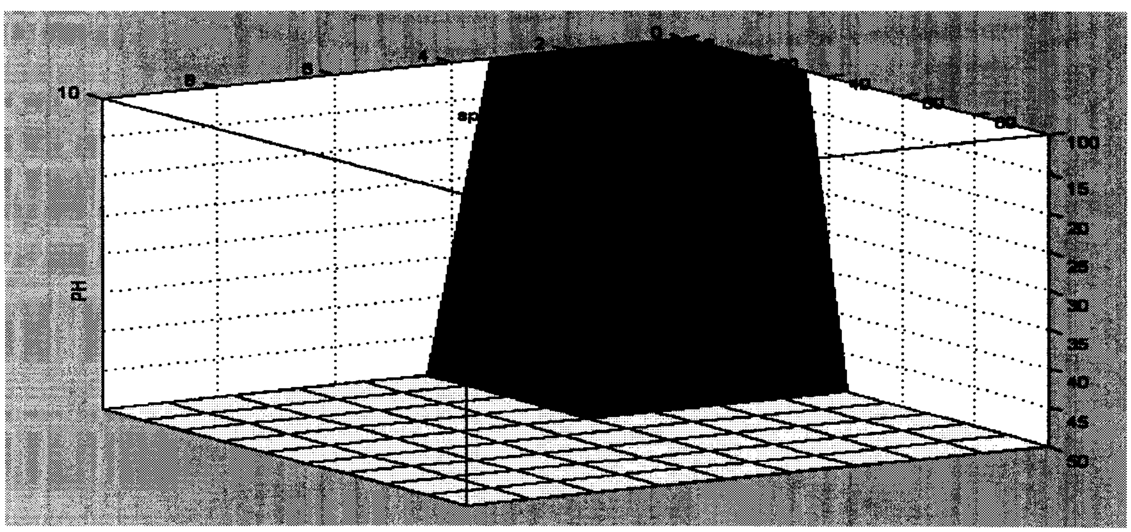


Figure-4.8(d) Plot between specific gravity, volume and PH for soap manufacturing system.

Plot between valve selection, chemical selection, and specific gravity exposed in Figure-4.8(e), plot shows valve opening is independent to the specific gravity of the soap it depends on chemical selection.

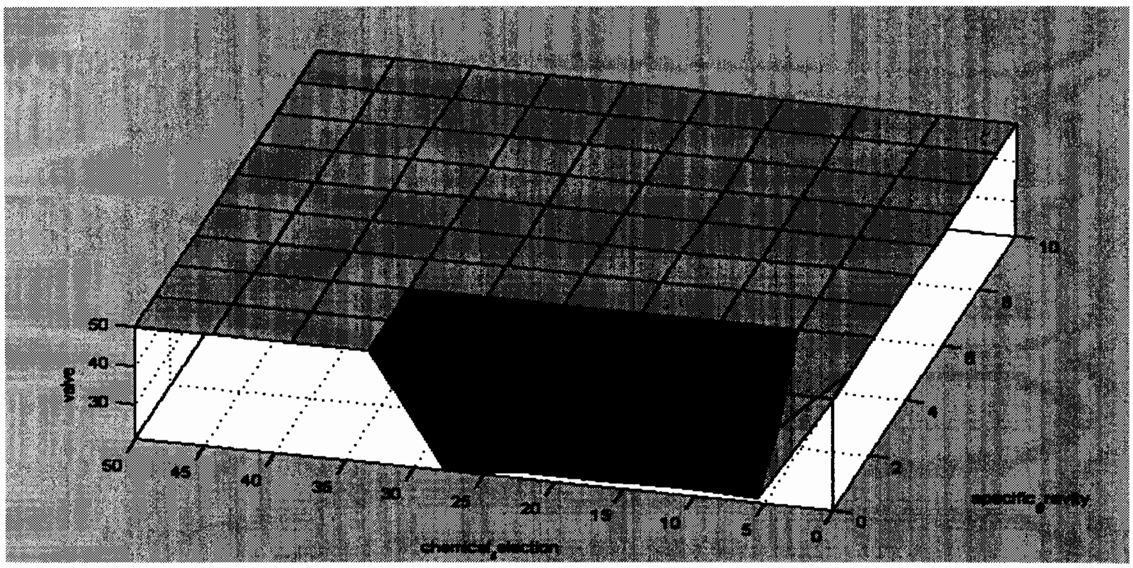


Figure-4.8(e) Plot between specific gravity, chemical selection and valve opening for soap manufacturing system.

Plot between chemical selection, specific gravity, and PH of the soap at current temperature exposed in Figure-4.8(f), plot shows PH does not depend on the specific gravity it depends on chemical selection.

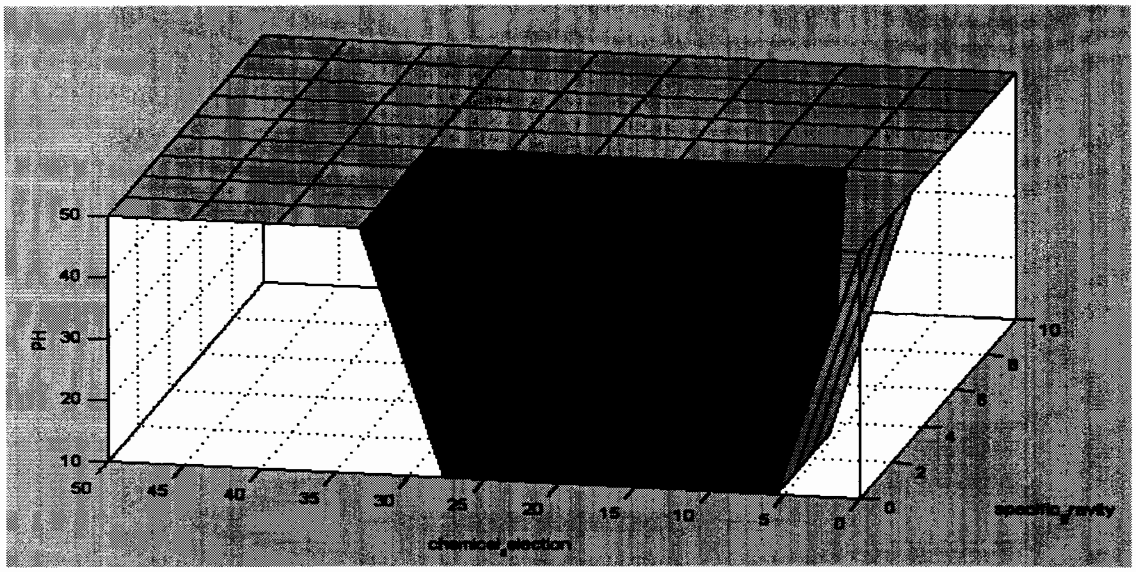


Figure-4.8 (f) Plot between specific gravity, chemical selection and the PH for soap manufacturing system.

Plot between specific gravity, chemical selection and mixing speed exposed in figure-4.8(g), plot shows mixing speed is independent to the chemical selection it depends on the specific gravity of the soap.

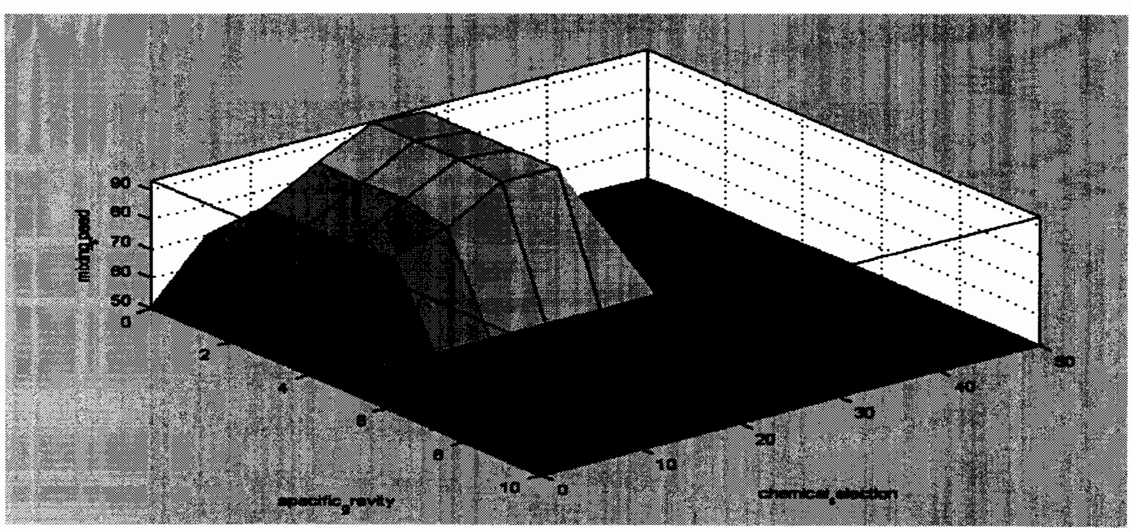


Figure-4.8(g) Plot between specific gravity, chemical selection and mixing speed for soap manufacturing system.

Plot between temperature, chemical, specific gravity and viscosity exposed in Figure-4.8(h), plot shows temperature depends on specific gravity and is independent to the viscosity of the soap.

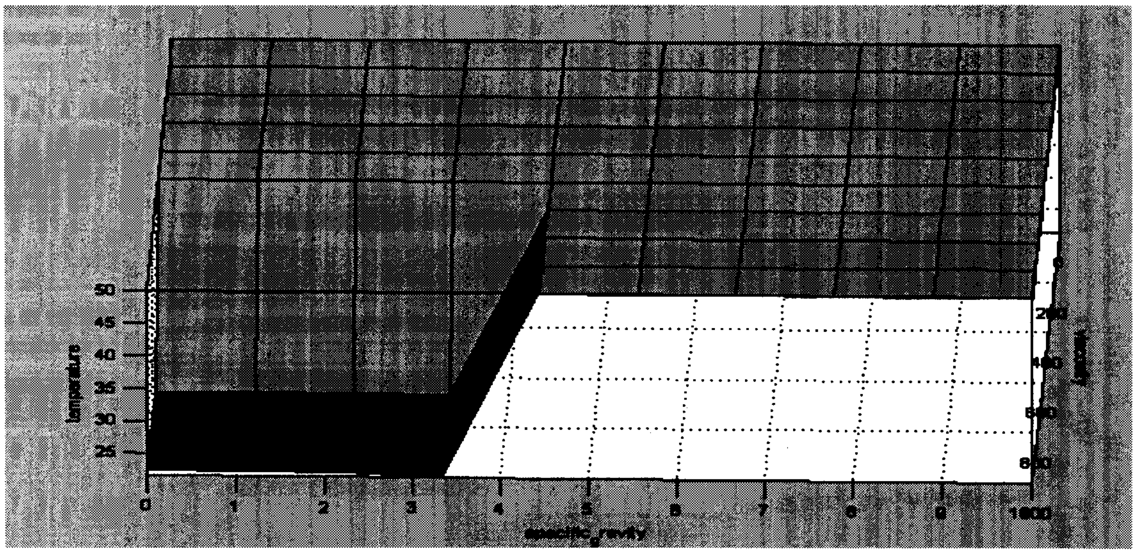


Figure-4.8(h) Plot between viscosity, specific gravity and temperature for soap manufacturing system.

Plot between temperature, volume, and viscosity exposed in Figure-4.8(i), plot shows temperature of soap depends on viscosity it does not depend on volume of the soap.

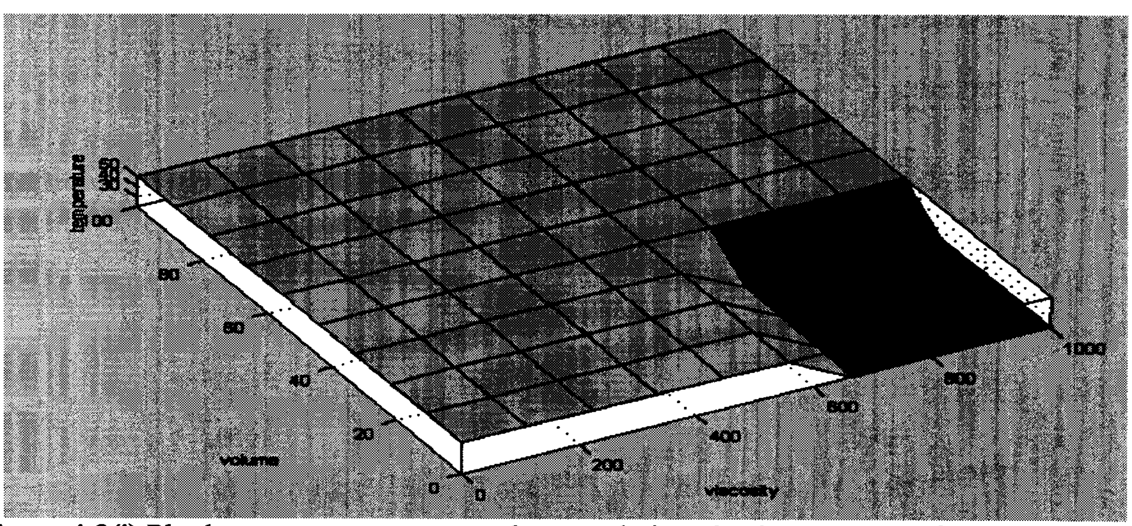


Figure-4.8(i) Plot between temperature, volume and viscosity for soap manufacturing system.

4.4.3 RESULTS OBTAINED FOR SYRUP MANUFACTURING SYSTEM.

MATLAB simulation results obtained for the proposed syrup manufacturing system are exposed in the above figure-4.8(a-i). It is clear from output plot that specific gravity and viscosity influence on the temperature, PH, and mixing speed, while the chemical selection effects on the valve selection.

Table-4.4 shows the output defuzzified values for temperature, temperature time, mixing speed, mixing time, valve, valve opening time, PH at current liquid temperature, PH time

From MATLAB simulation and also the defuzzified values from manual calculation corresponding to the input variable viscosity=1.4' specific gravity=1.7 and chemical selected =16

Table-4.4 MATLAB simulation results for soap manufacturing system.

	Tem.	Tem. time	Mixing Speed	Mixing time	PH	PH Time	valve	Valve Opening Time
MATLAB Simulation	22.2	62.7	80.3	62.7	10	62.7	33.5	62.7
Manual Calculated Values	23.4	61.6	83	61.6	11.5	61.6	34	61.6

The result obtained from MATLAB simulation and for designed model calculations are quite satisfactory and there is small error between them.

4.4.4 CONCLUSION AND FUTURE WORK

Soap is an important anionic, disinfecting detergent which is frequently used in homes for bating, washing and many other ways in every day life. Soap comes in many different shapes and forms like liquid, powder and solid bar. Proposed soap manufacturing model is designed to facilitate the manufacturing industry to enhance the production on large scale. Designed model is very efficient and simple in its performance and has flexibility to adjust the input and output parameters easily according to the soap requirement. Design model provides the satisfactory Defuzzified values from MATLAB simulation. Proposed soap manufacturing model provides stable state of soap in small interval of time.

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