WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

STREAM: INDUSTRIAL CONTROL

FINAL PROJECT TITLE: “Design and control cane level in chute using fuzzy controller in Fincha Sugar”

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Submision date 12/10 /2011 EC

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DECLARATION

We declare that the work contained in this project titled “design and control of cane level in chute using fuzzy controller in finchaa sugary factory” is our original work. We have not copied from any other students work, from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for us by another person. We assure that we agree with all written above with our signature as follows.

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CERTIFICATE

This is to certify that the dissertation entitled “design and control cane level control in chute using fuzzy controller in finchaa sugary factory “has been carried out by the above group members. For partial fulfillment of the award of degree of bachelor of science in electrical and computer engineering (industrial control)

Head of Department name	Advisor Name
______________________	______________________
Signature	Signature
______________________	______________________
Date	Date
_______/______/_______	_______/______/_______
Remark______________________	comment ______________________

ACKNOWLEDGEMENT

First of all, we would like to thank the Almighty God for his blessing us invaluable gifts of health, believes, love, hope, patience, protection, granting us with wisdom, the opportunity of an education and for letting us to finish this project and in general for the knowledge and strength he offered. Secondly, we would like to thank Wolkite university college of Engineering and technology especially electrical and computer engineering department who gave us the chance of doing this project. Our sincere appreciation and gratitude goes to our advisors Mr. Yohanis S for his advice, assistance and valuable guidance by sparing valuable time in giving information in the preparation and successful completion of this work. Finally, thank you all those involved directly or in directly helping us out during our design and simulation which we cannot state out every one of them. Mostly, special thanks also to our family and friends for their external support throughout our academic career and we acknowledge to all who have visited our project and gave us good comments, spiritual strengths and courage and showed special interests on it.

ABSTRACT

In sugar factor process control, cane level control is one of the most basic aspects. By using fuzzy logic, designer can realize lower development cost, superior feature and better end product. In this project, level of cane in chute is control by using fuzzy logic concept. Due to the non-linearity in the input parameters a fuzzy based controller proved to be more effective. This project Deals with the integration of the developed fuzzy inference system with the Simulink model of dc cane carrier motor for maintaining the cane level during the crushing of cane in a sugar mill for optimum cane juice extraction for this purpose, a simulation system of fuzzy logic controller for cane level control is designed using simulation packages of MATLAB software such as Fuzzy Logic Toolbox and Simulink. The designed fuzzy logic controller first takes information about inflow and outflow of cane in chute than maintain the level of cane in chute by controlling its output speed of cane carrier motor. is designed on five rules using two-input and one-output parameters. At the end, simulation results of fuzzy logic-based controller it shows that fuzzy logic controller has better stability, fast response and small overshoot.

KEYWORDS: Simulink, sugar mill, cane carrier, Donnelly chute, juice extraction, fuzzy algorithm, fuzzy controller

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ACRONOMY

AC	ALTERNATE CURRENT
BOA	BISECTOR OF AREA
COA	CENTROID OF AREA
DC	DIRECT CURRENT
FAM	FUZZY ASSOCIATIVE MEMORY
FIN	FUZZY INTERVAL NUMBER
FIS	FUZZY INFERENCE SYSTEM
FLC	FUZZY LOGIC CONTROLLER
GA	GENETIC ALGORITHM
HIS	HELLENIC INDUSTRY OF SUGAR
LIFE	LABORATORY FOR INTERNATIONAL FUZZY ENGINEERING
LOM	LARGEST OF MAXIMUM
MEE	MULTIPLE EFFECT EVAPORATOR
MF	MEMBERSHIP FUNCTION
MOM	MEAN OF MAXIMUM
MY	MARKETING YEAR
PD	PROPORTIONAL DERIVATIVE
PI	PROPORTIONAL INTEGRAL
PID	PROPORTIONAL INTEGRAL DERIVATIVE
SF	SCALING FACTORS
SOM	SMALLEST OF MINIMUM

CHAPTER ONE

1. Introduction

Industrial automation is becoming increasingly important in the manufacturing process because it improves the production efficiency with higher consistency and quality. In a sugar mill for optimum juice extraction, the cane level in Donnelly chute is to be maintained. The conventional controllers used for the automation of a process in an industry show poor performance when the process is non-linear. Because of the nonlinearity controllers based on mathematic models are very difficult to design with traditional control theory. However fuzzy control algorithm is an efficient control method best suited for nonlinear process. So, it is suitable to design fuzzy inference system for cane level controlling.

1.1. Back ground

During sugar manufacturing the cane billets are converted into cane fiber and this cane fiber is crushed for the extraction of cane juice. The cane juice extracted contains impurities and the clarification of the cane juice is the next step. The juice clarification process converts the impurities into a thick paste of mud which settle down in the clarifier vessel while clarified juice overflows the clarifier vessel. The supply of cane for processing is very uneven and this uneven supply of cane during juice extraction adversely affects the sugar mill efficiency and causes mill breakdown, stoppage and jamming. In this project we have developed an intelligent two input fuzzy controller which maintains the cane level at desired height in Donnelly chute during cane crushing by nullifying the variation in cane supply and roll speed. The fuzzy controller for maintaining the cane level in Donnelly chute generates the signal for controlling the speed of motor driving the rake carrier depending upon the cane amount on rake, level of cane in Donnelly chute and roll speed. We have discussed the cane juice extraction process and some important terminology used in sugar mills. The two inputs fuzzy controller is simulated for five different cases by using fuzzy toolbox of 'MATLAB® version. The fuzzy logic process involves the following steps:

- ✓ Input/output membership functions
- ✓ Rules
- ✓ Decision making (Interpretation of rules)
- ✓ Defuzzification

The advantages provided by a FLC are listed below:

- ✓ It is simple to design.
- ✓ It provides a hint of human intelligence to the controller.
- ✓ It is cost effective.
- ✓ No mathematical modeling of the system is required.
- ✓ Linguistic variables are used instead of numerical ones.
- ✓ Non-linearity of the system can be handled easily.
- ✓ System response is fast.
- ✓ Reliability of the system is increased.
- ✓ High degree of precision is achieved.

1.2. Statement of problem

The control of cane level in chute and flow between Donnelly chutes is a basic problem in the process sugar factory. If the level of cane is very low, then there may be chances of passing of cane fiber uncrushed from the mill and if the level of cane is very high then there is a chance of breakdown due to heavy load on mill. Therefore, to maintain the level of cane fiber an operator is deputed who will maintain the level of cane fiber in Donnelly chute by varying the speed of cane carrier motor. The level of cane in chutes must be controlled, and the flow must be regulated There are many alternative controller design theories that can be used to control the level of cane in chute. Proportional control, PI control, PD control and PID control will be investigate to determine which controller is the best for cane level control. Therefore, in certain cases where there is deficient of experience with the process, it is sometimes quite impossible to achieve a satisfactory performance. For this reason, it is desirable to introduce fuzzy logic controller.

1.3. Objective

1.3.1. General objective

The main objective of this project is to design and control of level of cane in chute by using fuzzy logic controller.

1.3.2. Specific objective

- ✓ control the level of cane in Donnelly chute by varying the speed of cane carrier motor
- ✓ Design a FIS to control the level of cane in Donnelly chute.

- ✓ To propose the Fuzzy Logic Controller in control of chute system.
- ✓ To generate appropriate voltage to vary the speed of cane carrier motor in order to maintain the level of cane fiber in Donnelly chute

1.4. Scope of the project

The study outlines the design and control of cane level in Donnelly chute of sugar factory.

The scopes of the project are as followings:

- ✓ Study the characteristic Donnelly chute Apparatus
- ✓ Study on Fuzzy Logic controller toolbox.
- ✓ Design the graphical programming for Fuzzy Logic Controller.

1.5. Significance of the project

The project is mainly designed for industrial control. It used for similar purposes if there is importance. It is a good bench mark for further work and improvement industrial control. Sometimes the number of cane entering into chute and at this time uncrushed cane fiber passed through the chute reversly small amount cane entering to chute and break down due to heavy load. This leads to fatigue in sugar factor industry. Therefore, the work initialized that control speed of motor based on amount of cane entering into chute and with level of chute automatically solve these problems and functioned for more.

1.6. Project limitation

Our project have some limitation which requires future modifications. Means that our control level of cane fiber in chute we designed do not indicate condition at which speed is high and less than expected value and only operator understand this condition by looking value.

1.7. Project outline

This project is organized in five chapters. The first chapter gives an overview of the project that gives the introduction of control system. It consists of project background, statement of problem, objective, and scope.

Chapter two covers literature review which included the controller used to control of motor running. Some brief explanation on the results obtained.

Chapter three covers the flow of methodology and description of each procedure. The details of the design and controls are discussed. It also consists of theory of controller. Chapter four focuses on the result, analysis and discussion of this project.

Chapter five includes the conclusion and recommendation of the project

CHAPTER TWO

2. Literature review

We know that almost all industrial processes are nonlinear. Derivative term of the PID causes large change in process output even if there is a small noise available at the input. Fuzzy control is an intelligent and easy to design control method which generates fast and accurate result [1]. It does not require the knowledge of a mathematical model of a process. Fuzzy, neuro or neuro-fuzzy controllers are the examples of unconventional controllers [2] and [3]. The concept of Fuzzy Logic was conceived by Lotfi Zadeh, a professor at the University of California at Berkley. He concluded that in the absence of precise input information it is possible to reach a conclusion by allowing partial set membership rather than crisp set membership [4]. A fuzzy logic system (FLS) is able to simultaneously handle numerical data and linguistic knowledge. It is a nonlinear mapping of an input data vector into a scalar output [5]. Japan first started research activities on fuzzy logic. A research institute, Laboratory for International Fuzzy Engineering (LIFE) started functioning in 1993. The Japanese researchers are the leaders in the practical implementation of Fuzzy theory and now have more than 2000 patents in the area. Now fuzzy logic controllers are being increasingly applied in areas where system complexities, development time and costs are the major issues. Prof. E. Mamdani and his student, S. Assilian, build first ever fuzzy controller in England in 1973 at the University of London. After experimenting they concluded that for controlling the speed of a steam engine a fuzzy based controller was fore efficient as compared to conventional controller [6]. A system response with and without fuzzy controller is shown in Fig. 4(a) and 4(b) respectively. A cement kiln built in Denmark in 1975 was the first industrial application of fuzzy logic. Canon developed a fuzzy based auto-focusing camera. The camera's fuzzy control system uses 12 inputs 13 fuzzy rules. A fuzzy based industrial air conditioner designed by Mitsubishi heats and cools five times faster as compared to the previous design, reduces power consumption by 24%, increases temperature stability by a factor of two, and uses fewer sensors. A fuzzy logic controller to control the temperature of the water bath was designed. It was observed that the response of the fuzzy controller was faster than the conventional PID Controller. It was also concluded that FLCs are much closer in spirit to human thinking and decision-making [7].

A fuzzy logic controller on the basis of operator experience was designed for controlling bonded ball size and shear strength density parameters for the wire bonding process. The fuzzy controller shows improved process control [8]. It is difficult by conventional controller to maintain the pH in metal precipitation and wastewater neutralization processes. A fuzzy logic controller was proved efficient in bringing the pH of acidic wastewater at desired level and thereafter maintaining it [9]. A fuzzy logic controller was developed for controlling the induction motor drive and it was more efficient as compared to conventional controller [10]. Conventional and fuzzy controllers for controlling the brightness of a LED lamp were designed. It was proved experimentally that the PI controller needs the least memory and run time whereas the fuzzy logic controller requires the most memory and run time [11].A fuzzy logic controller was developed for an automated car braking system. Braking performance observed in term of distance and velocity to prevent collision or accident for fuzzy, PI and PD type controllers [12]. A fuzzy controller was developed to control the output power of a pulse width modulated inverter used in a wind energy conversion system. The fuzzy controller was well efficient to track and extract maximum power from wind energy conversion system. It is also important to note that a fuzzy logic can be interfaced with a conventional control

The sugar is one of the largest sectors of economy. After two consecutive years of decline, the sugar production started to resurge in marketing year (MY) 2010-11 and has gained strength in 2011-12 (Amit Aradhey, 2011).India's domestic sugar market is estimated at US$ 5 billion. About 45 million Indian farmers and their families are dependent on the sugar cultivation. Sugar is India's second largest agro processing industry and about 3 % of India's cultivable land is under sugar. In India, Maharashtra accounts for the maximum production of sugar followed by Uttar Pradesh (Amitabha Sen, 2005).

Production of sugar from sugar cane route has been an age-old practice and the technology has been fairly stabilized in India for quite some time. In the present context, where the prices of sugar cane, sugar produced and molasses are fixed by the government authorities, the only methods for generating profits for sugar mills are by way of reducing manufacturing costs where steam and fuel economy plays a vital role. Plant automation packages are available now a days which provide savings in bagasse or steam or electricity and also improve the sugar quality (Forbes Marshall, 2003).A microprocessor-based system was developed at CEERI Pillani for the control of pH in Juice clarification in sugar industries well back in 1986 (Laxmi Narayan et al, 1986). Considering the system complexities and non-linear nature of such systems, soft computing tools like Fuzzy logic find wide application in modeling and control of various sugar processes.

Fuzzy logic, invented by Lotfi Zadeh in the mid 1960s provides a representation scheme and a calculus for dealing with vague or uncertain concepts. It is a paradigm for an alternative design methodology which can be applied in developing both linear and non- linear systems for embedded control. Zadeh originally devised the technique as a means for solving problems in the soft sciences, particularly those that involved interactions between humans, and/or between humans and machines.In Japan, Terano, inspired by Zadeh's work introduced the idea to the research community in about 1972. This led to active research and a host of commercial applications, almost entirely in the area of physical system control. In 1990, a research institute namely LIFE (Laboratory for International Fuzzy Engineering) started functioning under the leadership of Terano (LIFE, 1993). The Japanese researchers have been a primary force in advancing the practical implementation of Fuzzy theory and now have more than 2000 patents in the area. There has been rapid developments of the theory and application of Fuzzy logic to control systems. Fuzzy logic controllers are being increasingly applied in areas where system complexities, development time and costs are the major issues (Oon Pin Lim et al, 1998). New generation of Fuzzy logic controllers are based on the integration of conventional and Fuzzy controllers. The two new paradigms – artificial neural networks and Fuzzy systems try to understand a real-world system starting from the very fundamental sources of knowledge, i.e. patient and careful observation, measurements, experience and intuitive reasoning and judgements rather than starting from a preconceived theory of mathematical model (George J. Klir and Bo Yuan, 2003).

The Fuzzy logic controller (FLC) provides a means of converting a linguistic control strategy. C.C. Lee (1990) has presented a survey of the FLC. The author has described a general methodology for constructing an FLC. In particular, attention has been given to fuzzification and defuzzification strategies, the derivation of the data base and fuzzy control rules, the definition of fuzzy implementation and analysis of fuzzy reasoning mechanism. Some of the representative applications of the FLC from laboratory level to industrial process control have also been represented. Advanced Fuzzy controllers use adaptation capabilities to tune the vertices or supports of the membership functions or to add or delete rules to optimize the performance and compensate for the effects of any internal or external perturbations. Learning Fuzzy systems try to learn the membership functions or rules (Timothy J. Ross, 1997).Radu- Emil and Hans Hellendoorn (2011) have addressed a brief survey on industrial applications of Fuzzy control. The following classification of the control system has been proposed with this regard.- Control systems with Mamdani Fuzzy controller - Control systems with Takagi – Sugeno Fuzzy controller - Adaptive and predictive control system

The integration of probability theory and Fuzzy logic for solving engineering problems has been a recent area of interest for the researchers. Probabilistic Fuzzy logic systems are proposed for modeling and control problems (Amir H. Meghdadi et al, 2003 ;Dusmanta Kumar Mohanta et al, 2005). Zhi Liu and Han - Xiong Li (2005) have introduced the design of such a system with application to a robotic system.The implementation of Fuzzy logic has picked up momentum in chemical and sugar industries also. Fuzzy set theory had been effectively used in the evaluation of environmental performance of traditional beet sugar plants (Krajnc et al, 2005). The focus was on development of a method for assessment of sugar production in order to track improvements towards environmental sustainability and zero emissions goal in beet sugar plants.

Vassilis G. Kaburlasos (2001) has presented novel mathematical tools developed for improving prediction of sugar production for Hellenic sugar industry (HSI), Greece. In the context of his work, a population of measurements was represented by a FIN (Fuzzy Interval Number) producing improved prediction results. Dumitrache and M. Caramihai (1999) developed a Fuzzy controller for an enzymatic conversion of a lignocellulosic residue. The objective was to assess the applicability of the Fuzzy theory to the identification of the relationship between the product formation and the inhibitor and substrate concentrations. In the report of the University of Oulu (Ulla Saarela et al, 2003), Control Engineering Laboratory, a Fuzzy modeling of a fed batch fermentation process is described. Jan Jantzen (1998) from Technical University of Denmark had outlined the various choices for an engineer to design a Fuzzy controller based on International standards. The author had also proposed a design procedure and a tuning procedure that carries tuning rules from the PID domain over to Fuzzy single loop controller. The idea is to start with a tuned, conventional PID controller, replace it with an equivalent linear Fuzzy controller, make the Fuzzy controller nonlinear and eventually fine-tune the non-linear Fuzzy controller. Ranganath Muthu and Elamin El Kanzi (2003), with the support of University of Bahrain Research Council had successfully implemented a Fuzzy logic controller for a pH neutralization process which is a classic example of a highly non-linear system. Such a system is really difficult to be controlled with the help of a conventional controller. The non linear change in the pH with the reagent flow makes close control of pH difficult (Peter Harriot, 1993).

Margarita Galibova and Hadjiski (2002) have studied the impact of Neural Networks' accuracy on the feedback / feed forward pH neutralization control performance. The authors have discussed two significant problems connected with the application of feed forward - the appearance of oscillations and the offset of the system output from its desired value.

2.1. Cane juice extraction mechanism

The function of the sugar factory is to produce crystal sugar from the juice in cane delivered to the factory. The cane is weighted and dumped in the cane carrier which carries these cane billets to the shredder. The cane is first passed through two sets of rotating knives. The first one is called cane knives. It is rotating at about 700 rpm and cut the cane into pieces.

Cane knives are also used as leveler to maintain the level of cane on cane carrier. The second set is called as shredder knives. It rotates slightly more than cane knives. These two sets of knives prepare the fiber of cane which is around 1 – 2 centimeters. The cane carrier carries cane fibers and feed it to Donnelly chute which is approximately 3 meters of height. The juice extraction from the cane takes place by feeding cane fibers through a series of the mills called the milling train. In a sugar mill there are five to six cane crushing mills but seventy-five percent cane juice is extracted by the first mill. The crushing mill consists of two big size rollers arranged in a horizontal at bottom. The rollers are 50-100 cm in diameter and 1-3 m long. The bottom two rollers are fixed. The rolls turn 6-10 rpm, and the velocity of cane through them is 10-45 cm per seconds. The level of cane fiber in Donnelly chute is very crucial. If the level of cane fiber is very low, then there may be chances of passing of cane fiber uncrushed from the mill and if the level of cane fiber is very high then there is a chance of breakdown due to heavy load on mill. Therefore, to maintain the level of cane fiber an operator is deputed who will maintain the level of cane fiber in Donnelly chute by varying the speed of cane carrier motor. If the level of cane fiber is very low, then operator will increase the speed of the cane carrier so that level of cane fiber rise in Donnelly chute and if the level of cane fiber is very high then operator will decrease the speed of the cane carrier so that level of cane fiber falls in Donnelly chute. Various parameters of cane crushing mechanism:

- ✓ Speed of cane carrier motor–28-106 rpm.
- ✓ Total height of Donnelly Chute–1.8m
- ✓ Cane fiber is maintained at level 1.98m–2.2m for maximum extraction of cane juice. Schematic of the cane crushing mechanism in a sugar mill.

2.2. Important terminology of mill

Two rolls and the chute arrangement used for cane crushing are shown in Fig. 2.1. It has been investigated that the physical structure of mill effects the feed depth at which maximum crushing rate can be achieved. Means Roll Diameter (D) - A roll with groves is shown in Fig. 2.2. The diameter of roll when measured from the tip of groves is Do and Dg is the length of groves and D is the average diameter of roll. The mean diameter of roll is given as:

$D = Do – Dg$………………………………………. ………………………………….. (2.1)

Where Do = Outside Diameter of roll

Dg = Groove Depth Work

Opening (W) - The opening measured between the two rolls outside diameter is called as nib opening or set opening and represented by Ws. The opening measured between the mean diameters of two rolls is called work opening and is given as:

$W = Ws + Dg$……………………………………………………………………………(2.2)

Roll Surface Speed (S) - The surface speed of roll (m/s) is given as:

$S= (\omega \times D)/2$……………………………………………………………………………. (2.3)

Where ω is the angular velocity of the roll and (3) can also be written as:

$S = (\pi \times D \times N)/60$………………………………………………………………………… (2.4)

Where N is roll shaft speed in rpm

Optimum feed depth (Bc) - The thickness of cane blanket at the feed opening of the mill effects the juice extraction from the mill. The optimum feed depth is investigated and found as follows:

$Bc = (W+D)/2$ ……………………………………………………………………….. (2.5)

Contact Angle Between pair of Rolls (α) - The contact angle is the angle between the line joining the center of the two rolls and the line joining the center of roll to the point where chute touches the roll. The contact angle is given as:

$\cos\alpha = (D + W - Bc) / D$…………………………………………………… …………..(2.6)

Escribed volume (Ve) – The escribed volume (m3/s) is the volume of prepared cane passing through the work opening of the mill and is given as:

$Ve = Lr \times D \times S[1 + (W/D) - \cos\alpha) \cos\alpha$……………………………………………….. (2.7)

Where Lr is roll length

The average speed of cane blanket (Sf) at the point where chute touches the rolls is S Cos α. At the entry of chute the volume of cane passing the entry plane is given as:

$Ve = Lr \times Bc \times S \cos\alpha$ ……………………………………………………………... (2.8)

A=Lr×W =7960.5cm^2

Dimension of chute:

- ✓ Lc = Length = 180cm , Wc = Bc = Width = 43.5cm
- ✓ Dc = Lr = Depth = 183cm , Optimum feed depth (Bc) = 43.5c

The various parameters of mill

Lr = 183cm D = 75.5cm, W = 11.45cm, Bc = 43.5cm , α = 61° S = 16.6cm/s , Sf = 8.07cm/s

Pc = Mass density of prepared cane = 350Kg/m^3 ,Q is the mass flow rate of cane through the mill and is given as:

$Q = \rho c Lr D S[1 + (W/D) - \cos\alpha) \cos\alpha]$ ………………………………………………… (2.9)

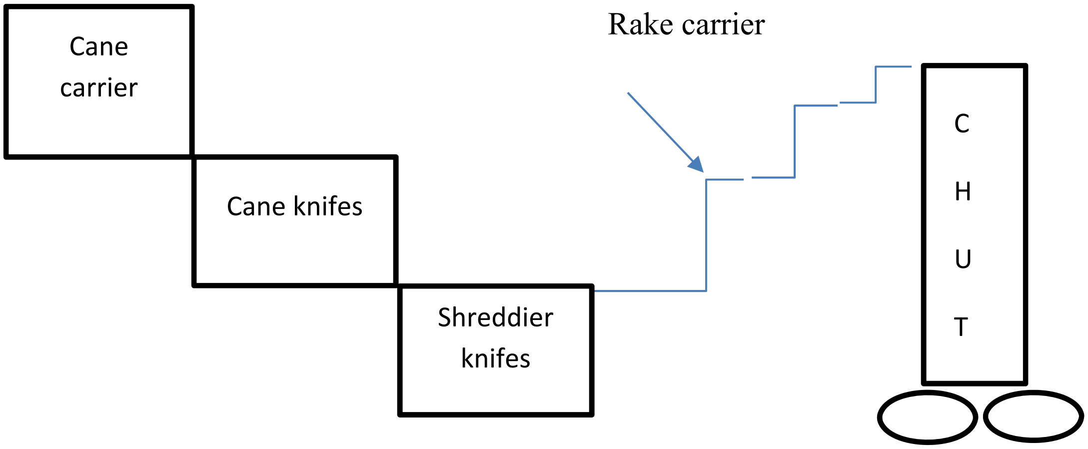


Figure 2. 1:juice extraction process

CHAPTER THREE

3. Methodology and Material

In Literature review we have discussed, control level of cane in Donnelly chute using fuzzy logic controller in sugar factory system and explanation of component commonly used in control and design the system.

3.1. Fuzzy model of cane level controller

Maintaining the cane level during cane juice extraction is an important task of the operator. A schematic of cane juice extraction from mill. Parameters of cane crushing mechanism are Speed of cane carrier motor, weight of cane and Total height of Donnelly Chute. Cane fiber is carried by cane carrier and finally dumped in Donnelly chute from where it is crushed by the rollers. For the maximum extraction of cane juice, the level of cane fiber is maintained. The amount of cane fiber carried by cane carrier varies due to non-uniformity of cane supply. If the level of cane fiber falls below the desired level, then the speed of cane carrier motor is to be increased and if the level of cane fiber rises above the desired level the speed of cane carrier motor is to be decreased for maintaining the desired level. Due to the non-linearity in the process a fuzzy based controller will be suitable for maintaining the desired cane fiber level in Donnelly chute. The fuzzy control system is designed using fuzzy logic tool box of MATLAB R2010b. Input parameter ‘Height’ is in the range (0 to 180cm), input parameter ‘weight is in the range (500Kg to 1000Kg) and output parameter speed’ is in the range 28RPM to 106RPM.

3.2. Methodology

Two design techniques adopted in this thesis were: mathematical modeling based on first principles; and via simulations. These two techniques complement each other as they are both needed to achieve desirable results. A simulation environment in MATLAB was built. Prior to running the simulation in MATLAB/SIMULINK, the fuzzy logic controller was designed. This was done using the fuzzy inference system (FIS) editor. The design of the fuzzy logic controller required choosing appropriate membership functions after which a convenient rule base was created.

3.2.1. Basic Block Diagram of the system

We can group block diagram as a general:

- Input unit
- Fuzzy controller unit
- Output unit

Block diagram

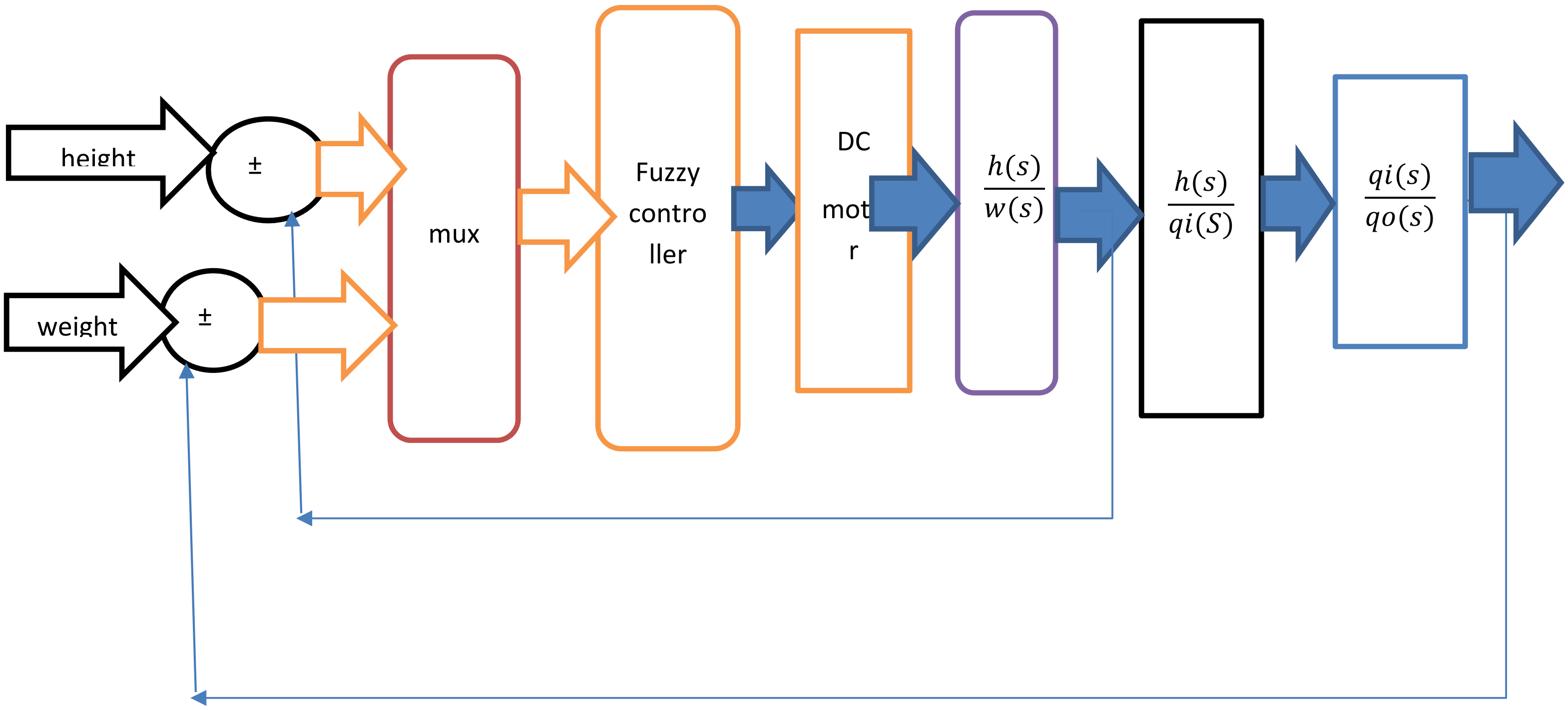


Figure 3. 1:block diagram of cane level control fuzzy controller

3.2.2. Flow chart

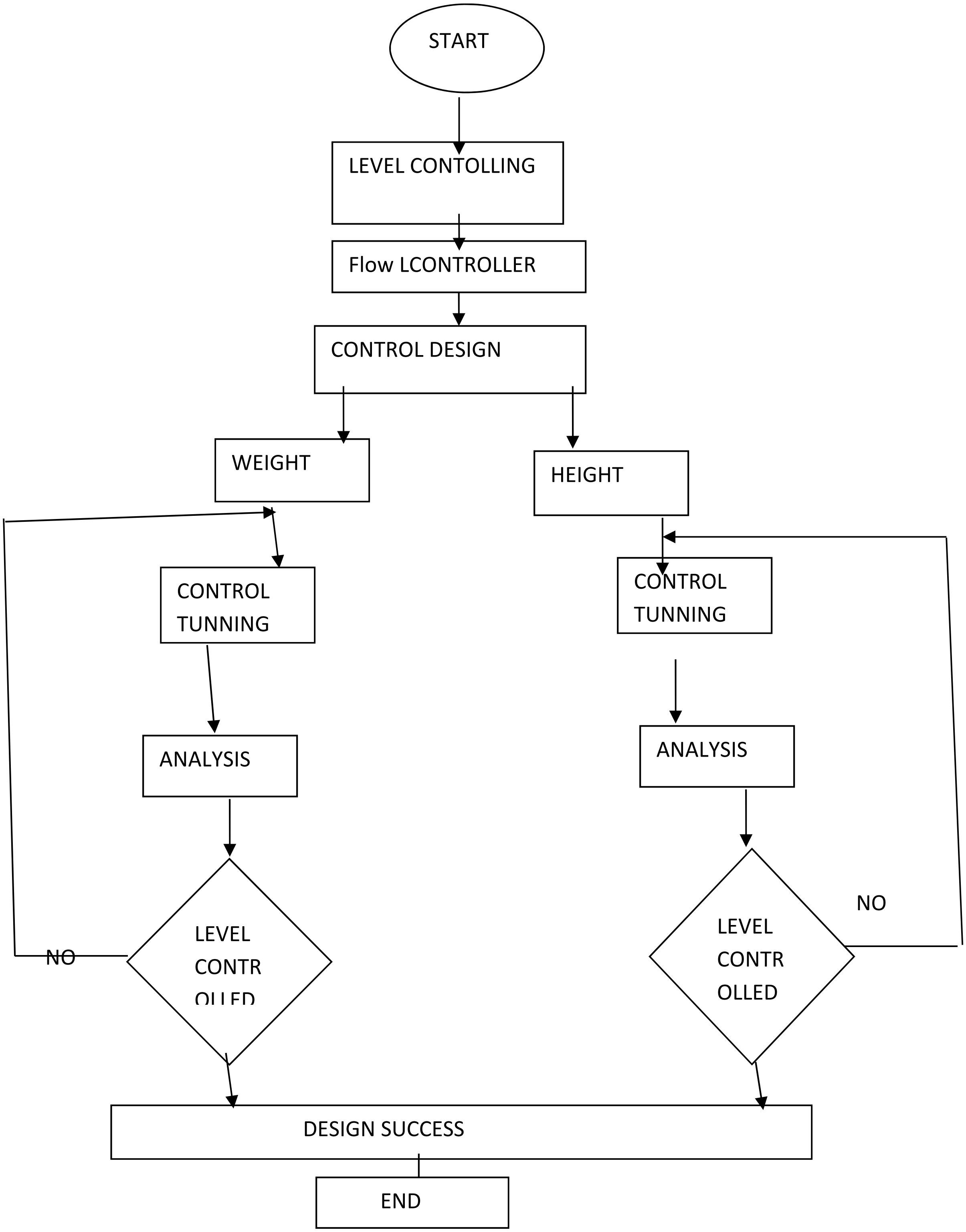


Figure 3. 2: flow chart

3.3. The system design and development

The system design and development describe the fundamental building blocks of the system which highlights the block diagram, operational framework, components and their specification.

3.4. Cane carrier dc motor model

3.4.1. Dc motor principles

the motors used in cane level control in this thesis is dc motor. There are several reasons to choose DC motors over AC motors. High performance (especially at low speeds), high power density, simplicity of control, and a large installed base help determine applications for DC motors. DC motors develop full-load torque at low speeds. This, combined with low inertias, result in excellent performance from DC motors. AC motors and controls have closed the performance gap, but general-purpose DC motors still outperform general purpose AC motors. To obtain comparable low-speed performance from an AC motor, much more expensive AC drives and motors must be used. The control system for a DC motor is much simpler and less expensive than an equivalent AC drive and Various parameters of separately exited DC motor are as follows:

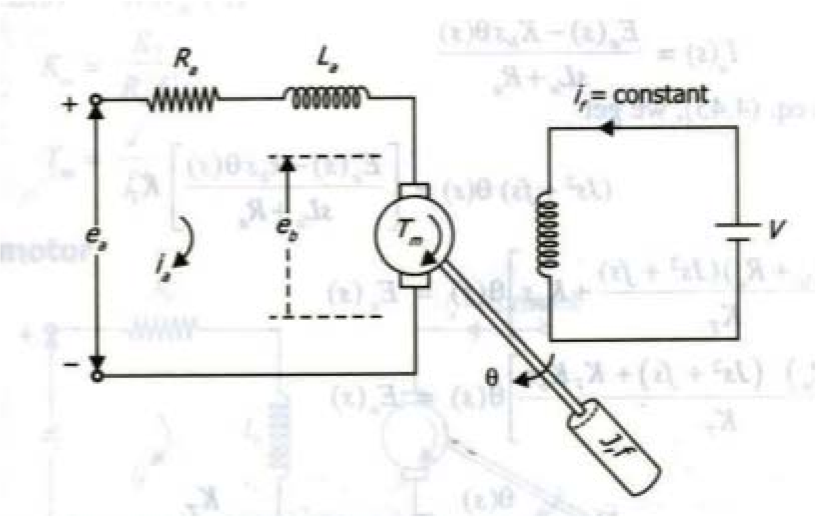


Figure 3. 3:separately excited dc motor

Ea = armature voltage (V)

Ra = armature resistance (Ω)

La = armature inductance (H)

Ia= armature current (Ia)

Eb = back emf (V)

ω = angular speed (rad/sec)

Tm = motor torque (Nm)

Θ = angular position of rotor shaft (rad)

Jm = motor moment of inertia (kgm2)

Kf = windage torque coefficient (Nms/rad)

Ke = torque constant of motor (Nm/A)

Kb = back emf constant (Vs/rad)

$Ea(t)\ RaIa(t) + Ia\frac{dia(t)}{dt} + Eb(t)$……………………………………………………………3.1

$Eb(t) = Kb\omega(t)$………………………………………………………………………………3.2

$Tm = KtIa(t)$……………………………………………………………………………...3.3

$Tm = Jm\frac{d\omega(t)}{dt} + Kf\,\omega(t)$……………………………………………………………….3.4

From equation (3.1) and (3.2) we get

$Ea(t)\ RaIa(t) + La\frac{dia(t)}{dt} + Kb\omega(t)$…………………………………………………………….3.5

From equation (3.3) and (3.4) we get:

$Ke\ Ia(t) = Jm\frac{d\omega(t)}{dt} + Kf\omega\ (t)$………………………..……………………………………..3.6

Laplace transform of equation (3.5) and (3.6) are given as:

$E_a(s) = R_a\ I_a(s) + L_a\ I_a(s).s + K_b\ (s)$……………………………………………………...…..3.7

$K_e\ I_a(s) = J_m\ W(s).s + K_f\ \omega\ (s)$ ………………………………………………………………..3.8

$$\frac{\omega\,(s)}{\mathrm{Ea}(s)} = \frac{ke}{Las+Ra})(\frac{1}{Js+Kb})\ldots\ldots 3.9$$

3.5. Fuzzy controller design

In order to design a Fuzzy Inference System (FIS) to control the level of cane fibers in Donnelly chute, we must describe the operation of system linguistically. A text block of FIS is shown Four components of a fuzzy controller are fuzzifier, rule base, inference engine and defuzzifier It has been calculated that the flow rate is 26.6Kg/cm which will remain constant whereas the feed rate will be varied depending on the height of cane in chute and amount of cane available in rake carrier. The rate at which cane is dumped in chute is known as feed rate and the rate at which cane is crushed by the rolls of mill is called flow rate. When the cane level in chute is at 0cm, 30cm or 60cm then the feed rate of cane is increased by 30%, 20% or 10% of flow rate. If the cane level in chute is at 90cm then the feed rate of cane should be same as flow rate of cane i.e. 26.6Kg/sec. If the cane level in chute is at 120cm, 150cm or 180cm then the feed rate is decreased by 10%, 20% or 30% of flow rate. The control algorithm to design a fuzzy controller is shown below.

Two input parameters selected for the fuzzy controller are ‘HEIGHT’ and ‘WEIGHT’. Input parameter ‘HEIGHT’ measures the level of cane fiber in Donnelly Chute in centimeters and input parameter ‘WEIGHT’ measures the weight of cane in cane carrier in Kilograms. The output parameter selected for this design is ‘SPEED’ which is the speed of the carrier motor in rpm. The universe of discourse of input parameter ‘HEIGHT’ is in the range 0 to 180cm and its graphical representation is shown in Fig.3.4. The universe of discourse of the input parameter ‘HEIGHT’ is fuzzified into seven triangular linguistic variables as follows:

3.6. Membership Function Design

3.6.1. Input Linguistic Variables

The inputs to the Fuzzy Logic Controller are:

- ✓ height(h)
- ✓ weight(w)

EL (Extreme Low): [0 30]

VL (Very Low): [0 30 60]

L (Low): [30 60 90]

JR (Just Right): [60 90 120]

H (High): [90 120 150]

VH (Very High): [120 150 180], EH (Extreme High): [150 180]

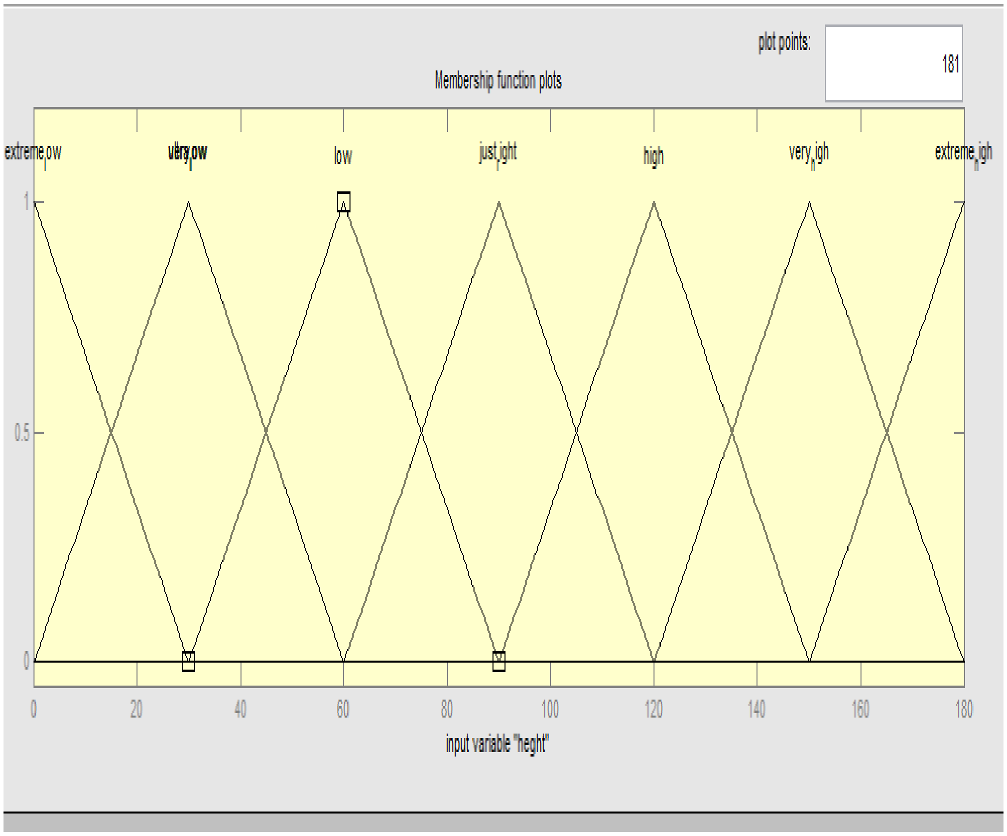


Figure 3. 4: membership function of height

3.6.2. Fuzzy Sets and MFs for Input Variable height(h)

Table 3. 1: Linguistic Variables of Input Parameter 'HEIGHT

Linguistic Variable	Interpretation	Range(m)
EL	Extreme Low	[0 30]
VL	Very low	0 30 60
L	Low	30 60 90
JR	Just Right	60 90 120
H	High	90 120 150
VH	Very high	120 150 180
EH	Extreme high	150 180

3.7. Fuzzy design of system

The universe of discourse of input parameter 'WEIGHT' is in the range 500Kg to 1000Kg and its graphical representation is shown in Fig.3.4. The universe of discourse of the input parameter 'WEIGHT' is fuzzified into eleven triangular linguistic variables as follows:

3.7.1. Fuzzy Sets and MFs for Input Variable weight (w)

SL (Super Low): [500 550]

UL (Ultra Low): [500 550 600]

EL (Extreme Low): [550 600 650]

VL (Very Low): [600 650 700]

L (Low): [650 700 750]

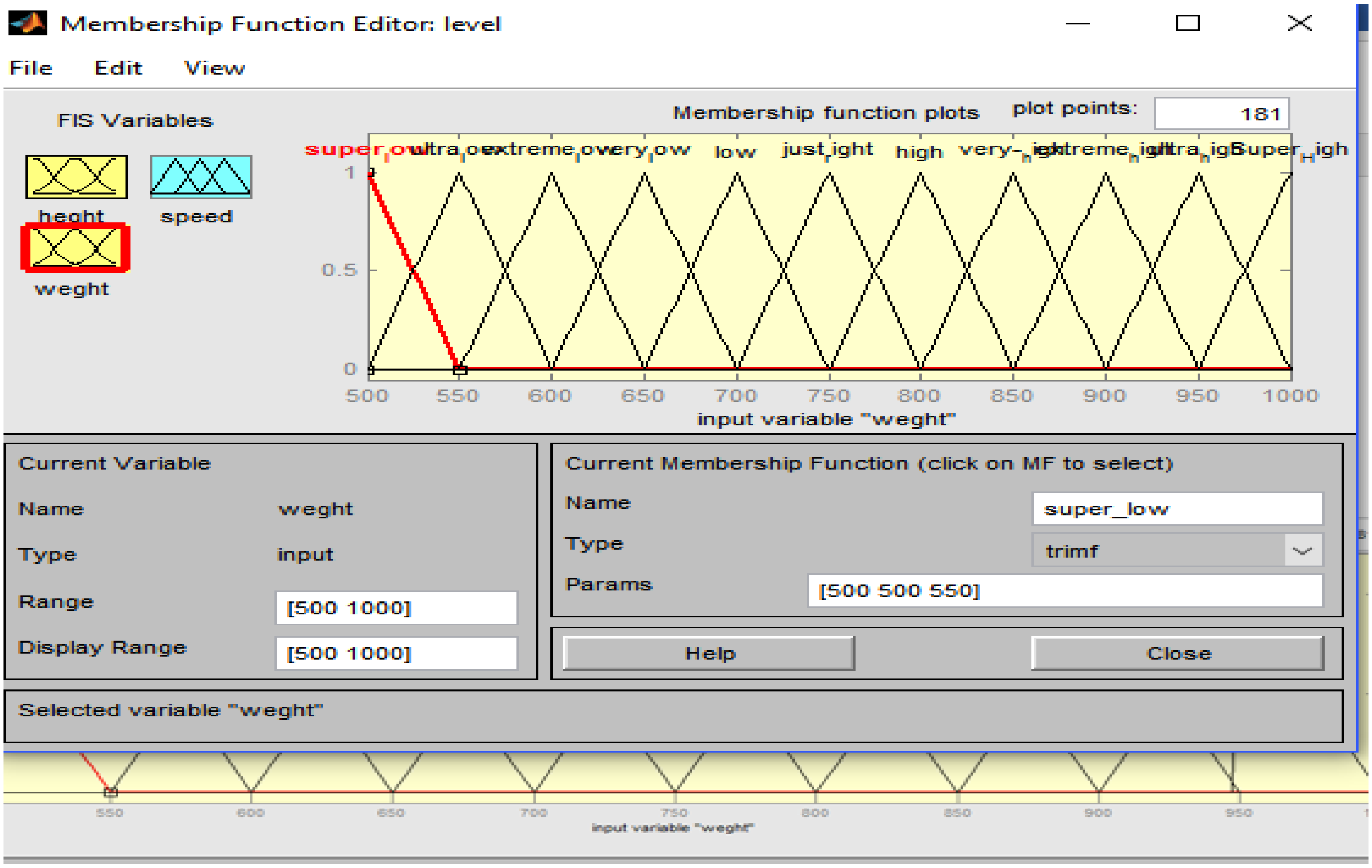
JR (Just Right): [700 750 800]

H (High): [750 800 850]

VH (Very High): [800 850 900]

EH (Extreme High): [850 900 950]

UH (Ultra High): [900 950 1000] ,SH (Super High): [950 1000]



plot points: 181

Current Variable

Name weght

Type input

Range [500 1000]

Display Range [500 1000]

Current Membership Function (click on MF to select)

Name super_low

Type trimf

Params [500 500 550]

Selected variable "weght"

Figure 3. 5:membership function of „weight"

Table3.2: Linguistic Variables of Input Parameter 'WEIGHT"

Linguistic Variable	Interpretation	Range (Kg)
SL	Super Low	500 550
UL	Ultra-Low	500 550 600
EL	Extreme low	550 600 650
VL	Very Low	600 650 700
L	Low	650 700 750
JR	Just right	700 750 800
H	High	750 800 850
VH	Very high	800 850 900
EH	Extreme high	850 900 950
UH	Ultra-high	900 950 1000
SH	Super high	950 1000

The universe of discourse of output parameter ‘SPEED’ is in the range 28RPM to 106RPM and its graphical representation is shown in Fig.3.5.

3.8. Output Linguistic Variable

The universe of discourse of the output parameter ‘SPEED’ is fuzzified into seven triangular linguistic variables as follows:

3.8.1. Fuzzy Sets and MFs for Output Variable speed

VL (Very Low): [28 41]

L (Low): [28 41 54]

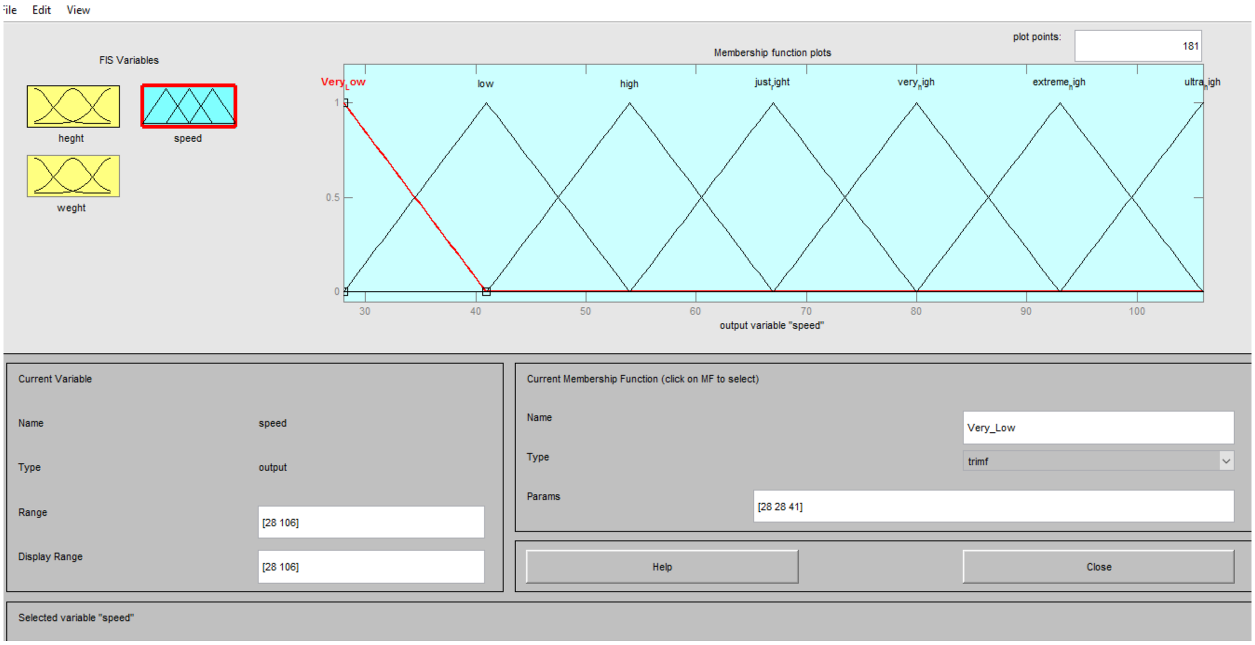
JR (Just Right): [41 54 67]

H (High): [54 67 80]

VH (Very High): [67 80 93]

EH (Extreme High): [80 93 106]

UH (Ultra High): [93 106]



plot points: 181

Name speed

Type output

Range [28 106]

Display Range [28 106]

Name Very_Low

Type trimf

Params [28 28 41]

Selected variable "speed"

Figure 3. 6:membership function of „speed‟

Table 3.3: Linguistic Variables of Input Parameter 'speed

Linguistic Variable	Interpretation	Range(rpm)
VL	Very Low	[28 41]
L	Low	[28 41 54]
JR	High	[41 54 67]
H	Just Right	[54 67 80]
VH	Very High	[67 80 93]
EH	Extreme High	[80 93 106]
UH	Ultra-High	[93 106]

Each triangular membership function of input and output parameters has 50% overlaps with its neighbor membership function. The surface viewer of FIS is shown in Fig.3.6. The fuzzy rules can be represented by a fuzzy associative memory (FAM) table as represented in the fuzzy rules are developed for the fuzzy controller which produces appropriate speed indication to run the cane carrier motor depending upon the height of cane fiber in Donnelly chute and weight of cane in cane carrier. Since the input parameter 'HEIGHT' is fuzzified into seven linguistic variables and the input parameter 'WEIGHT' is fuzzified into eleven linguistic variables therefore there arises seventy-seven rules. The fuzzy design in this work incorporates Mamdani's implication method of inference, which is one of the most popular methods in fuzzy control applications

3.9. Fuzzy Logic Controller

One of the reasons for the popularity of Fuzzy Logic Controllers is its logical resemblance to a human operator. It operates on the foundations of a knowledge base which in turn rely upon the various if then rules, similar to a human operator. Unlike other control strategies, this is simpler as there is no complex mathematical knowledge required. The FLC requires only a qualitative knowledge of the system thereby making the controller not only easy to use, but also easy to design.

3.10. Application Areas of Fuzzy Logic Controllers

The fuzzy logic Controllers are basically put to use when:

- ✓ The system is highly non-linear there by making the mathematical modeling of the system very arduous.
- ✓ The analytical form of the system is not provided, instead a linguistic form is provided.

- ✓ The precise identification of the system parameters.
- ✓ The system behavior has a vague characteristic under precisely defined conditions.
- ✓ The conditions themselves are vague.

The multiple effect evaporator (MEE) used to raise the concentration (brix) of sugar cane juice from a nominal value of 15 wt% to syrup with a brix of 72 wt%. The MEE under study in their work has five evaporator vessels (effects) connected in series. Heating steam for the first effect is exhausted from the turbine of the factory power plant. The vapour from the juice in the first vessel is used as heating source for the second vessel, and so on down the evaporator set. The vapour from the last effect is condensed in a barometric direct contact condenser. The last effect is connected to a vacuum pump thus cascading the pressures to provide the necessary temperature driving force for heat to flow down the MEE. Additionally, steam deductions are taken from the second, third and fourth effects for heating in the vacuum pans and juice heater, the major part from the second effect which supplies the vacuum pans. In the latter, crystallization of sugar from the syrup exiting the MEE takes place. The economy of sugar manufacturing depends strongly on the MEE because of the huge amount of thermal energy (steam) required during the process. The batch nature of the vacuum pan operation means that the demand of steam. Multiple-Effect Evaporator (MEE) Station from the MEE station is intermittent, thus disturbing strongly the MEE. The resulting fluctuations in the brix of the syrup in turn cause the vacuum pans to have variable boiling times and steam consumption, which further disturb the MEE. Thus, there is a kind of vicious interaction between the vacuum pans and the MEE. This fluctuation in the brix of the syrup is detrimental to energy economy. They have also suggested to work on the effect of tuning of MFs of several FLCs simultaneously on the results Cane juice clarification is an important chemical process applied in sugar mill after the extraction of raw juice from cane. The amount of cane fiber carried by cane carrier varies due to non-uniformity of cane supply. The continuous variation of cane in Donnelley chute during the cane juice extraction inversely affects the cane juice extraction efficiency of mill. A two-input fuzzy controller was developed to optimize the cane juice extraction process in 2014. The two-input fuzzy controller showed better result as compare to conventional controller in maintaining the cane level in Donnelly chute. The simulation result of two input fuzzy controller for four different cases are shown if. He fuzzy controller was developed to control the rake carrier motor speed in rpm depending upon the value of cane level in Donnelly chute, quantity of cane on rake carrier. The two inputs fuzzy controller was developed and simulated by using fuzzy logic toolbox of ‘MATLAB® version 7.11.0.584 (R2020b). It was concluded that if the roll speed is more uneven than fuzzy controller performance is better

3.11. Components of FLC

The inputs to a Fuzzy Logic Controller are the processed with the help of linguistic variables which in turn are defined with the aid of membership functions. The membership functions are chosen in such a manner that they cover the whole of the universe of discourse. To avoid any discontinuity with respect to minor changes in the inputs, the adjacent fuzzy sets must overlap each other [7]. Because of a small time, constant in Fuzzy Logic Controllers, this criterion is very important in the design of the same.

There are basically three essential segments in Fuzzy Logic Controller.

- ✓ Fuzzification block or Fuzzifier.
- ✓ Inference System.
- ✓ Defuzzification block or Defuzzifier.

3.12. Fuzzification

The first step towards designing a Fuzzy Logic Controller is choosing appropriate inputs which will be fed to the same. These input variables should be such that, they represent the dynamical system completely. Then the function of the Fuzzifier comes into picture. As discussed before, instead of using numerical variables, fuzzy logic uses linguistic variables for processing information. But since the inputs to the FLC are in the form of numerical variables (or in other words, crisp sets), they need to be converted into linguistic variables. technique involves outlining the membership functions for the inputs. These membership functions should cover the whole universe of discourse and each one represents a fuzzy set or a linguistic variable. The crisp inputs are thus transformed into fuzzy sets. Triangular MF, Trapezoidal MF, Bell MF, Generalized Bell MF or Sigmoidal MF can be used. Even a hybrid of any of the above Membership Functions can be used for fuzzification

3.13. Inference System

The inference system of a Fuzzy Logic Controller consists of the following three paradigms:

- ✓ Rule Base: It consists of a number of If-Then rules. The If side of the rule is called the antecedent and the Then side is called the consequence. These rules are very much similar to the Human thought process and the computer uses the linguistic variables, derived after fuzzification for execution of the rules. They very simple to understand and write and hence the programming for the fuzzy logic controller becomes very simple. The control strategy is stored in more or less the normal language.
- ✓ Database: - It consists of the all the defined membership functions that are to be used by the rules
- ✓ Reasoning Mechanism: - It performs the inference procedure on the rules and the data given to provide a reasonable output. It is basically the codes of the software which are process the rules and the all the knowledge based on a particular situation. It exercises a human brain type of attribute to methodically carry out the inference steps for processing the information.

3.14. Defuzzification Block or Defuzzifier

A defuzzifier performs the exact opposite function of a fuzzifier. It transforms the fuzzy variables (which are obtained as output after processing of the inputs) to crisp sets. The defuzzifier is necessary because in the real world the crisp values can only be taken as inputs to the other systems. Even though the fuzzy sets resemble the human thought process, their functionality is limited only to the above processes. A defuzzifier is generally required only when the Mamdani Fuzzy Model is used for designing a controller. in the input variables) and hence the output is crisp instead of fuzzy. This is counterintuitive since a fuzzy model should be able to propagate the fuzziness from inputs to outputs in an appropriate manner

Thus, we have seen that the designing of a Fuzzy Logic Controller (using the Mamdani Fuzzy Model) requires:

- ✓ The selection of appropriate inputs and their fuzzification.
- ✓ The definition of the input and output membership functions.
- ✓ The definition of the Fuzzy Rule Base.
- ✓ The defuzzification of the output obtained after the processing of the linguistic variables with the help of a proper defuzzification technique.

Each of them has to be designed based on the result that is desired from the system.

The various deffuzication techniques have been explained with the help of the figure shown above. The last two defuzzification techniques are rarely used because of their biased nature. The widest used technique is the Centre of Area (COA) method

Table 3.4:Fuzzy Rule Matrix

Weight Height	SL	UL	EL	VL	L	JR	H	VH	EH	UH	SH
EL	UH	EH	EH	VH	VH	H	H	H	JR	JR	JR
VL	EH	EH	VH	VH	H	H	H	JR	JR	JR	JR
L	EH	VH	VH	H	H	JR	JR	JR	JR	L	L
JR	VH	VH	H	H	JR	JR	JR	JR	L	L	L
H	H	H	H	JR	JR	JR	L	L	L	L	L
VH	H	JR	JR	JR	L	L	L	L	L	L	VH
EH	JR	JR	L	L	L	L	L	VL	VL	VL	VL

3.15. Design of the Fuzzy Logic Controller using MATLAB

While simulating the block diagram in MATLAB/SIMULINK®, the Fuzzy Logic Controller has to be programmed according to the aforementioned rules and knowledge base. The program is saved as an FIS file and it is later embedded into the Fuzzy Logic Controller. This FIS program can be checked with the help of FIS editor in MATLAB itself. The steps for the following are shown below, along with the membership functions, the rules and the surface plot viewed with the help of the FIS editor.

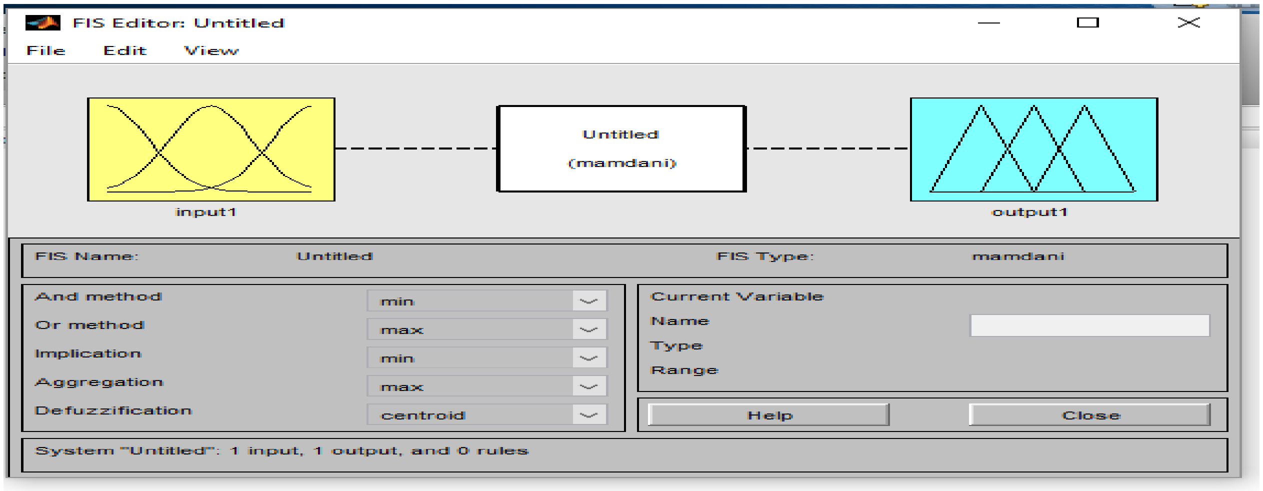
Step 1: The program for designing the Fuzzy Logic Controller using the FIS editor in MATLAB/SIMULINK® is as follows:

- ✓ The program for designing of the Fuzzy Logic Controller is written in a word file.
- ✓ The definitions for all the shown membership functions are written in the program.
- ✓ The 77 rules shown in tabular form in section below are written in the program according to the syntax provided by MATLAB.

- ✓ The document is saved with the extension .fis.

Step 2: The .fis file is now to be loaded in the FIS editor to view the membership functions, the rules and the rule surface plot.

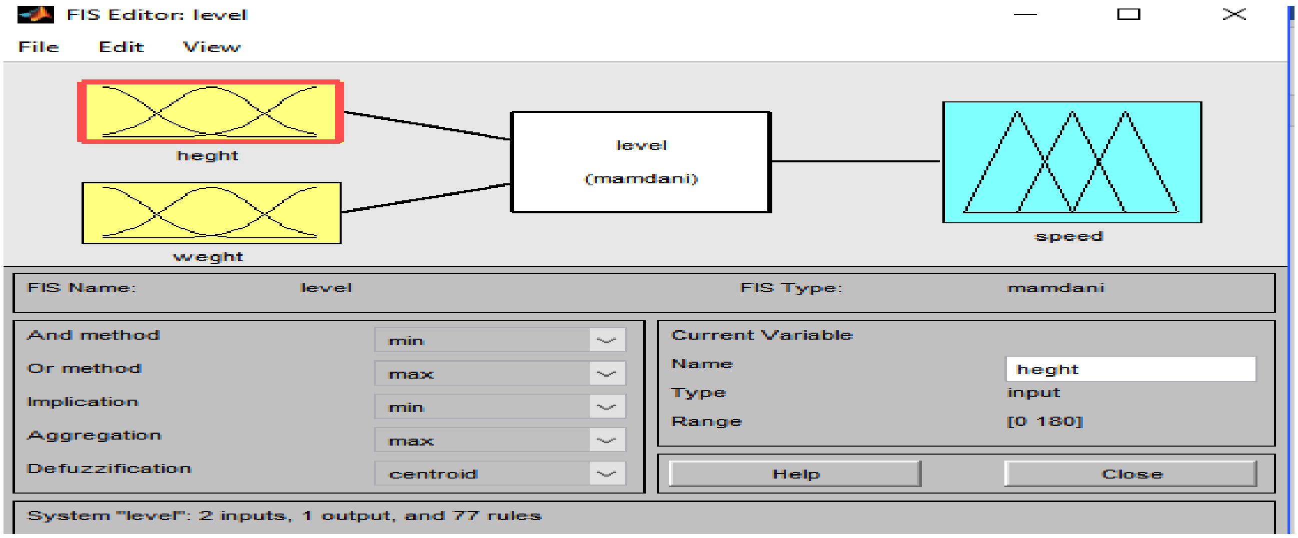
- ✓ On the command window of MATLAB fuzzy is typed to open the FIS editor.



FIS Name: Untitled
FIS Type: mamdani
And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid
System "Untitled": 1 input, 1 output, and 0 rules

Figure 3. 7:fis editor window in matlab

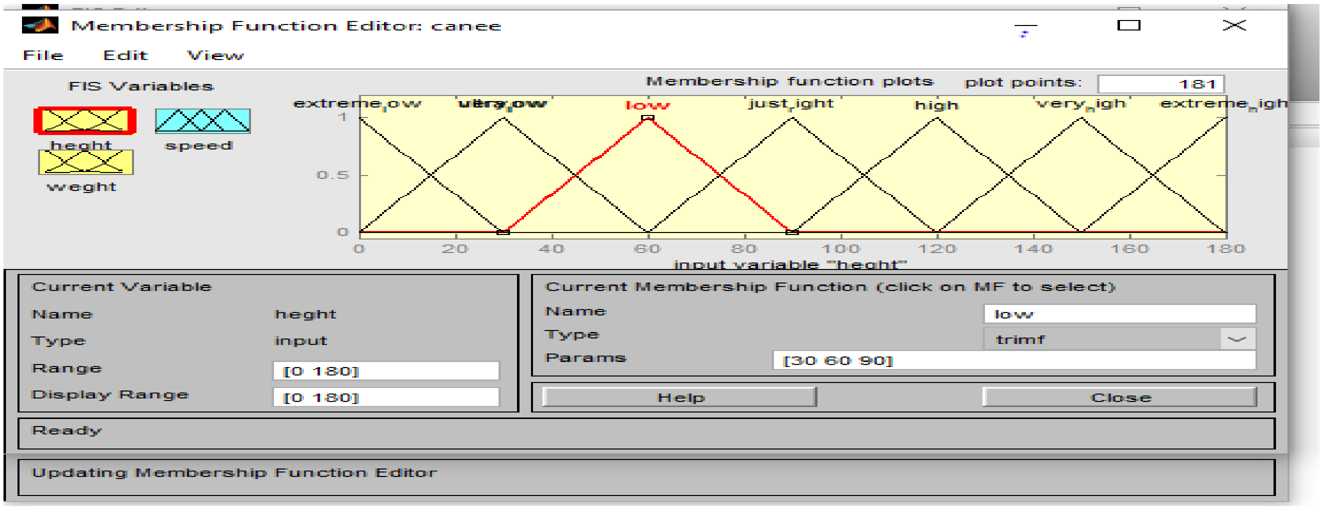
- ✓ Click File > Import > From file… and then browse the .fis file to open FIS editor: rules



FIS Name: level
FIS Type: mamdani
And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid
Name: heght
Type: input
Range: [0 180]
System "level": 2 inputs, 1 output, and 77 rules

Figure 3. 8:fis editor: rules window in matlab

- ✓ Click on any of the input or output to view the respective membership functions. The membership functions for inputs height and weight and for output Change in Control are shown in Fig 3.11, Fig 3.12 and Fig 3.13 respectively.
- ✓ In the FIS editor: rules window clicks on View > Surface to view the three-dimensional plot of the control surface. This plot is shown in Fig 3.14.
- ✓ Then in the FIS editor: rules window clicks on View > Rules to see the rules. The inputs can be changed in the window and respective outputs can be viewed.
- ✓ Fig 3.10, Fig 3.11, Fig 3.12and Fig 3.13 show outputs for two different inputs.



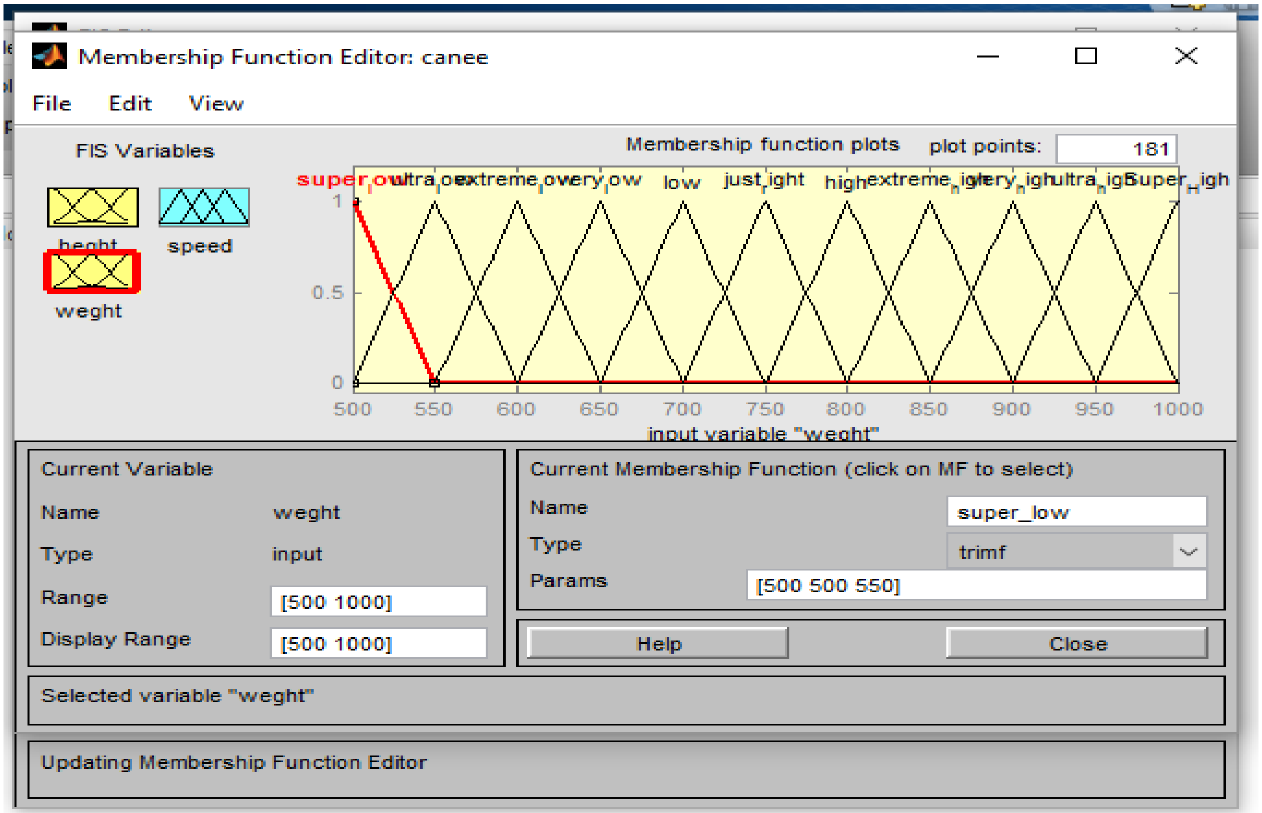
Current Variable
Name heght
Type input
Range [0 180]
Display Range [0 180]

Current Membership Function (click on MF to select)
Name low
Type trimf
Params [30 60 90]

Ready

Updating Membership Function Editor

Figure 3.*9*:membership function for the input height



Current Variable

Name weght

Type input

Range [500 1000]

Display Range [500 1000]

Current Membership Function (click on MF to select)

Name super_low

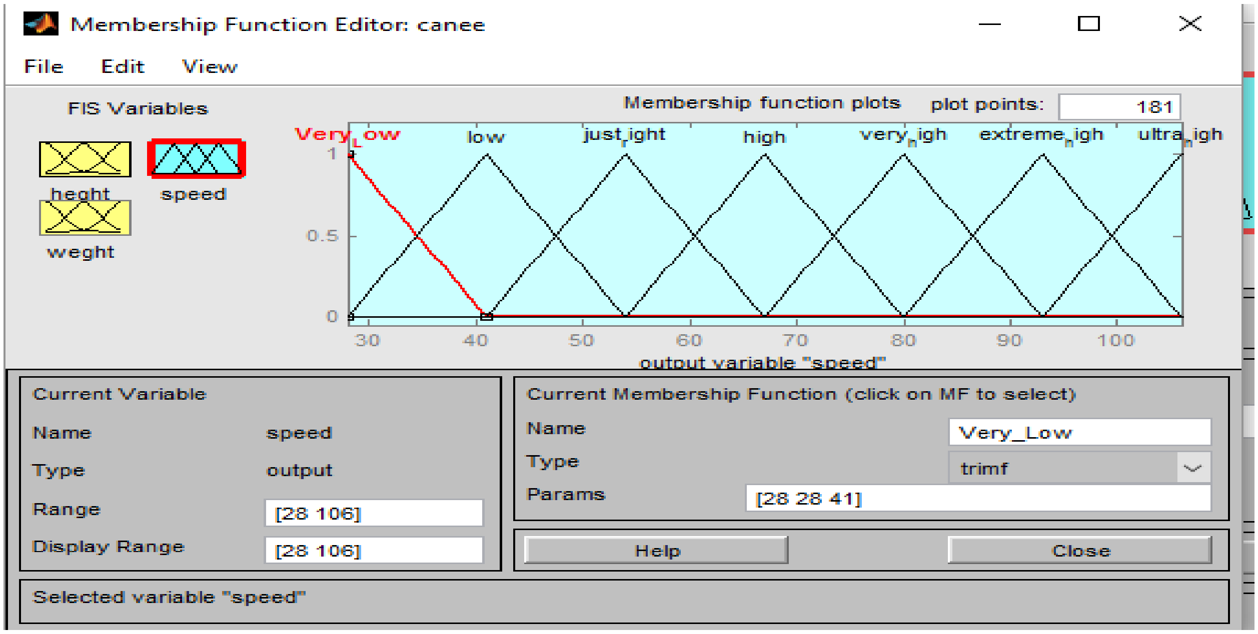
Type trimf

Params [500 500 550]

Selected variable "weght"

Updating Membership Function Editor

Figure 3.10: membership function for the input weight



Current Variable

Name speed

Type output

Range [28 106]

Display Range [28 106]

Current Membership Function (click on MF to select)

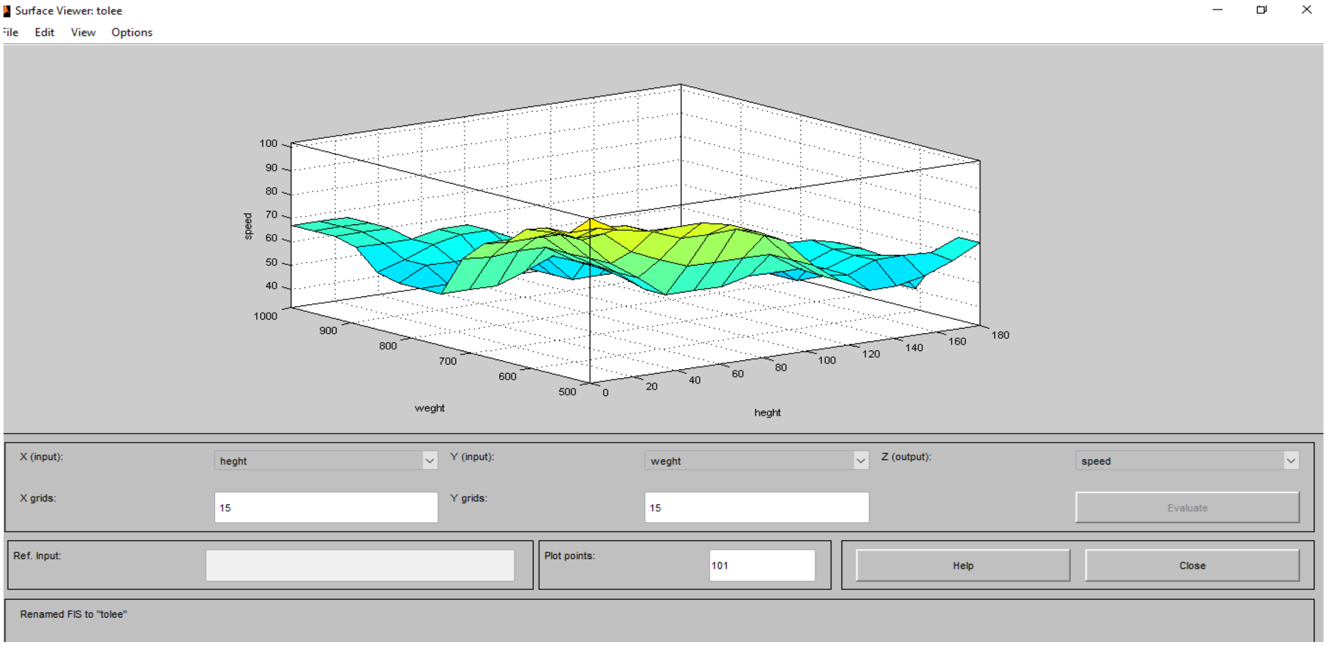
Name Very_Low

Type trimf

Params [28 28 41]

Selected variable "speed"

Figure 3.11: membership function for the output speed



X (input): heght
Y (input): weght
Z (output): speed
X grids: 15
Y grids: 15
Ref. Input:
Plot points: 101
Renamed FIS to "tolee"

Figure 3. 12: three-dimensional plot of the control surface

3.16. mathematical Model of cane fiber flow out (Qo)

In the process of controlling the level and flow of cane there should be mathematical model that express the relation of variable in the system. So in our case to determine the inflow of cane fiber the system model is as shown below.

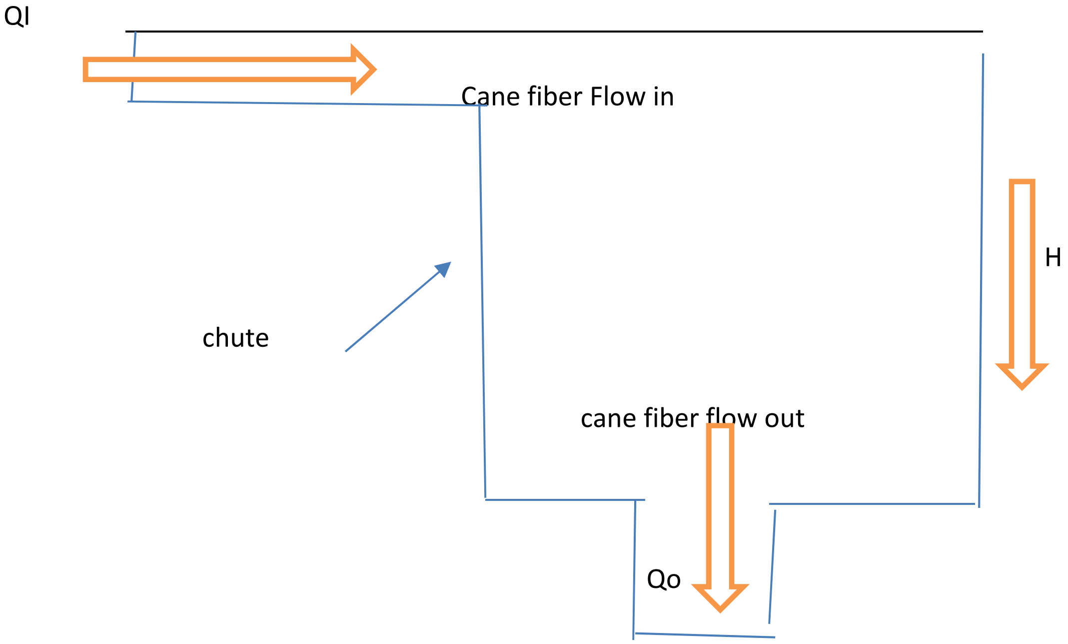


Figure 3. 13: modeling of cane fiber flowing out of chute

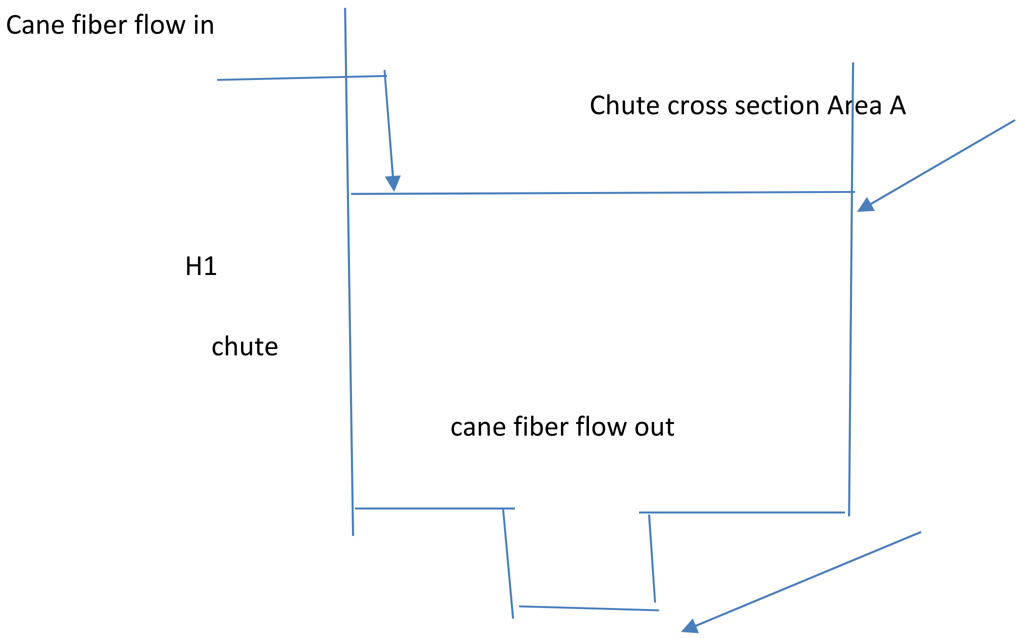


Figure 3.14: cane fiber flow out

In steady state condition, both qi and qo are same, and the height of the fiber level of the chute will be constant.

3.16.1. Resistance of fiber level system

The resistance for fiber flow in such a pipe or restriction is defined as the change in the level difference to a unit change in flow rate; that

$$\text{Resistance} = \frac{change\ level\ difference(m)}{change\ inflow\ rate(m^3/s)} \dots\dots\dots 3.9$$

$$\frac{dH}{dQ} = \text{R} \dots\dots\dots 3.10$$

3.16.2. Capacitance of fiber-level systems

The capacitance of a fiber is defined to be the change in quantity of stored fiber necessary to cause a unity change in the potential (head). The potential (head) is the quantity that includes the energy level of the system.

$$\frac{change\ \text{liquid stored}\ (m^3)}{change\ in\ \text{head ,m)}} \dots\dots\dots 3.11$$

Capacitance (C) is nothing but is cross sectional area (A) of the chute.

Rate of change of fiber volume in chute = flow in – flow out

$$Dq/dt = QI - QO \dots\dots\dots 3.12$$

Since volume is (area x height)

d(A*h)/dt =QI- QO……………………………………………………………………..3.13

Ad(h)/dt=QI- QO………………………………………………………………………3.14

And cross-sectional area can be replaced by capacitance

$C\frac{dH}{dt} = Qi - Q$……………………………………………………………………………….3.15

Where the resistance R may be written as

$R = \frac{dH}{dQ} = \frac{h}{qi}$ ……………………………………………………………………………….3.16

Then rearranging the equation (8) we get

$\frac{h}{R}$ = qi...3.17

Substitute equation (9) in equation (7), we get $\frac{CdH}{dt} = \frac{h}{R} - Qo$…………………………3.18

After simplifying above equation, the equation (3.18) becomes

$\frac{\mathbf{RCdh}}{\mathbf{dt}} - \mathbf{h}$ =-R qo…………………………………...3.19

Taking Laplace transform considering initial conditions to zero

RCsH(s) - H(s) = - RQ(s)..……………………………………………………………..3.20

The transfer function can be obtained as

$\frac{H(s)}{Qo(s)} = \frac{R}{(RCs+1)}$…..3.21

Where,

C=cross sectional area of the chute

R = radius of roller in chute

Where R=0.5m and C=A=0.078m^2

3.16.3. Mathematical model of cane fiber flow in (Qi)

Consider the single chute shown below

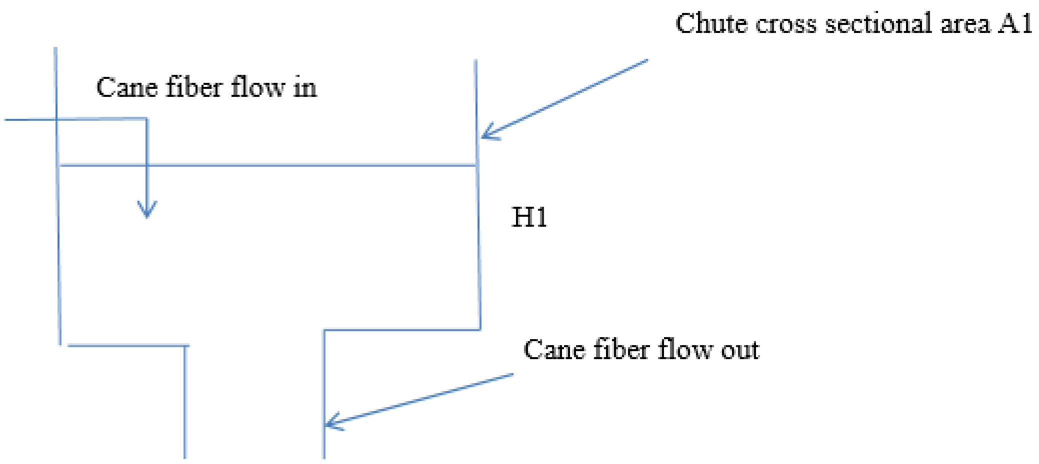


Figure 3. 15:mathematical model of cane fiber flow out

The system flow model is determined by relating the flow into the tank to that leaving via valve

The system flow model is determined by relating the flow into the chute

Qi - Qb = rate of change of cane level volume

$$Qi - Qb = \frac{dV1}{dt} = A\,\frac{dH1}{dt} \qquad \text{3.16.1}$$

Where,

A = cross sectional area of chute 1

V_1= volume of cane in chute 1 (V)

Qi = flow in rate

Qb = flow rate out of chute

If chute is assumed to behave like a standard sharp-edged orifice, then the flow through chute will be related to the fluid level in the chute, H, by the expression

$$Qb = Cdb*ab\sqrt{2gH1} \qquad \text{3.16.2}$$

Where, A= cross sectional area of the orifice. Represents the dimensions of valve B and the flow channel in which it is mounted.

Cdb = discharge coefficient of chute

g=gravitational constant = 0.98 m/sec

Assumes C_{db} is a constant and, therefore, that **Q** is proportional to the square root of the level **H** for all possible operating condition

In a practical valve the flow rate $\mathbf{Q_b}$ will be some general nonlinear function of level **H**

Qb =f (H1…………………………………………………………………...3..16.3

Combining equation 3.16.1 and 3.16.3 gives,

$$A\frac{dH1}{dt} + f(H1) = Qi \text{………………………………………………………………3.16.4}$$

The system model, equation 3.16.4 is a first order differential equation relating input flow rate Qi, to the output cane fiber level, H1

In order to make it useful for control systems purposes, it must be linear equation by considering small variations about a desired operating level of cane in the chute

Let, H1 = H1' + h1

H1' is the normal operating level and is a constant H is a small change about that level. Then, for small variations of h1 about H', can approximate the function f (H**)** by the straight-line tangent at H1'

Let the inflow Qi consist of a steady component Qi' plus a small change **qi**, then if Q'0' is the steady state outflow corresponding to Qb, and then we can rewrite equation 3.16.4 as:

$$\frac{\boldsymbol{Adhi}}{\boldsymbol{dt}} + \boldsymbol{Q'b} + \boldsymbol{qb} = \boldsymbol{Q'i} + \boldsymbol{qi} \text{…………………………………………………........................3.16.5}$$

This can be rewritten, with reference to figure 3.3 as,

$$\frac{\boldsymbol{Adh1}}{\boldsymbol{dt}} + \boldsymbol{f(H'1)} + \boldsymbol{h1} * \boldsymbol{D} = \boldsymbol{Q'i} + \boldsymbol{qi} \text{……………………………………………………………...…3.16.6}$$

Where the coefficient is the slope of the valve characteristics at the level H'1

$$D = \frac{\delta f(H'1)}{\delta H1} \text{…………………………………………………………...……………………3.16.7}$$

When the level is constant, with **qi=0** and **h=0**, then equation 3.16.5 gives the steady state relation for flow and level

f (H1’) =Qi’…………………………………………………………………..3.16.8

Subtracting equation 3.16.8 from equation 3.16.5 and then rearranging gives the linear; first order differential equation for the single tank system,

$\frac{Adh1}{dt} + h * D = qi$…………………………………………………...................................3.16.9

Where kb =$D^{-1} = \frac{1}{D}$ where D =$\frac{1}{Kb}$ The time constant T =$\frac{A}{D}$

$\frac{T*Ddh1}{dt}$ + h1*$\frac{1}{Kb}$= qi ………………………………………………………………..……..3.16.10

(T*$\frac{1}{Kb}\frac{dh}{dt}$) +h1 $\frac{1}{Kb} = qi$……………………………………………………………...3.16.11

$\frac{1}{Kb}$[($T\frac{dh}{dt}$) + h1] = qi……………………………………………………….……......3.16.12

$T\frac{dh1}{dt} + h1 = Kb * qi$……………………………………………………………3.16.13

Taking Laplace transforms gives the single chute system transfer function,

[T.sh1] + h1 Kb*qi   h1 [Ts + 1] = kb*qi

$\frac{H(s)}{qi(s)} = \frac{kb}{Ts+1}$ ……………………………………………………………………………3.16.14

Where Kb=1/D=1/4.21=0.24 and T=A/D=0.019m^2

The equation of flow rate can be calculated from inflow rate to out flow rate in equation 3.16.13 and 3.16.14 above

$$\frac{qi(s)}{qo\ (s)} = \frac{RTS + R}{KbRCS + Kb}$$

Then let RT=P and KbRC=D

$\frac{qi(s)}{qo\ (s)} = \frac{PS+R}{DS+Kb}$ ………………………………………………………………………3.16.15

Then we can put here the values of each variables as below:

Kb=0.24 , D=0. 0094m.^3, C=0.0783m^2, T=0.039S,R=0.5m, P=0.0095m^3

The effects of weight with its height can be derived using equation of mass flow rate and volume flow rate as we express below equation.

where $\frac{\Delta m}{\Delta t} = \frac{p\Delta v}{\Delta t}$ $\frac{\Delta m}{\Delta t} = pAv$……………………………………………….3.16.16

Mass flow rate volume flow rate,And V =Ah

$d\frac{m}{t} = \frac{PAdh}{dt}$, by taking Laplace transform on both side

sm(s)=pAsh(s)

$\frac{h(s)}{m(s!} = \frac{1}{pA}$ ……………………………………………………………………....3.16.17

Where PA =$\frac{h(s)}{m(s!} = \frac{1}{q}$ from eq (3.16.16 \$ 3.16.17)

Where:q=350Kg/m^3*0.0783m^2=27.405kg/m

CHAPTER FOUR

4. Result and discussion

A simulation run is performed on the ‘MATLAB® version 7.11.0.584 (R2020b) platform. The result of the simulation is shown in Table4.1. Figure below shows the variation in cane fiber in chute Figure 4.9 shows the speed of cane carrier motor (in cm/s). mathematical and experimental analyses of control systems can be carried out easily since the signals are very simple functions of time .Which of these typical signals to use for analyzing system characteristics may be determined by the form of the input that the system will be subjected to most frequently under normal operation .if a system is subjected to sudden disturbances, a step function of time may be a good test signal, and for a system subjected to a shock input, a pulse or an impulse function may be best. So that in our case the control system of our design is subject to sudden disturbance.due to that we consider the step input.

MATLAB Simulink design

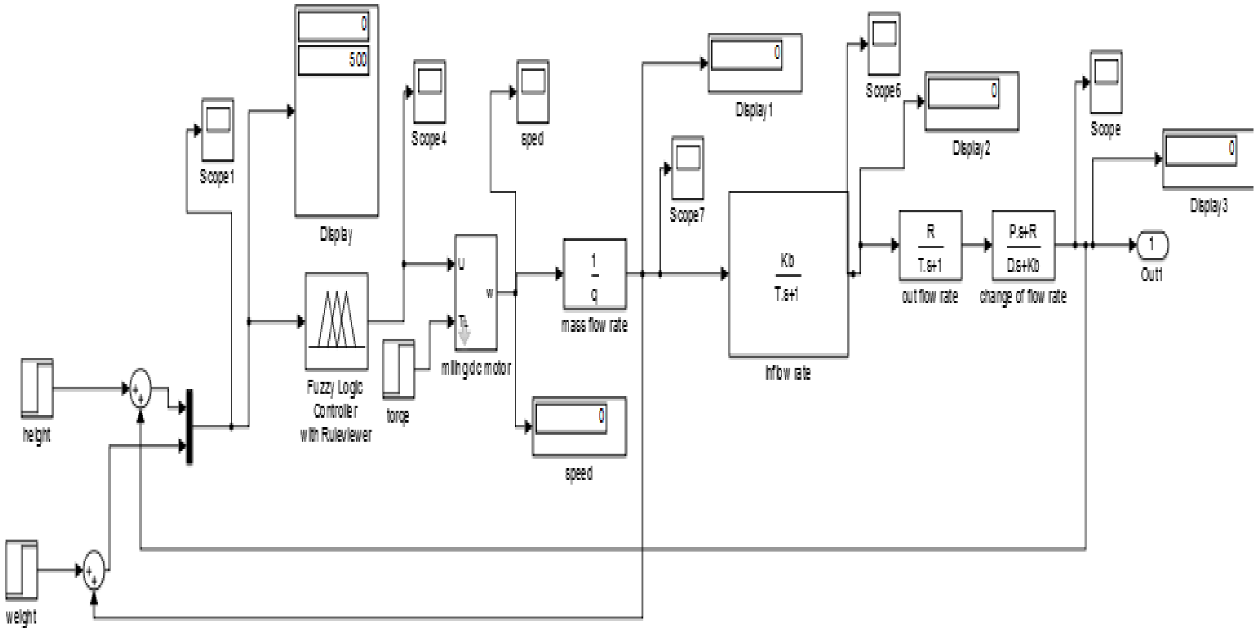


Figure 4. 1: MATLAB Simulink design

Table 4.1: Cane Level in Chute = 60cm (H) and Cane Level in Chute = 90cm (H)

S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	44.63	101
2	550(UL)	41.03	92.4
3	600(VL)	40.9	92.1
4	650 (VL)	34.95	78.8
5	700(L)	34.57	77.9
6	750(JR)	23.94	54
7	800(H)	24.09	54.3
8	850(VH)	24.29	54.8
9	900(EH)	29.72	67
10	950(UH)	29.72	67
11	1000(SH)	29.72	7

S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	41.16	92.7
2	550(UL)	40.6	91.5
3	600(VL)	35.24	79.4
4	650 (VL)	34.95	78.8
5	700(L)	24.01	54.2
6	750(JR)	24.01	54.2
7	800(H)	24.09	54.3
8	850(VH)	29.72	67
9	900(EH)	29.5	66.5
10	950(UH)	29.5	66.5
11	1000(SH)	29.72	66.5

Table4.2 Cane Level in Chute = 60cm (H) and Cane Level in Chute = 90cm (H)

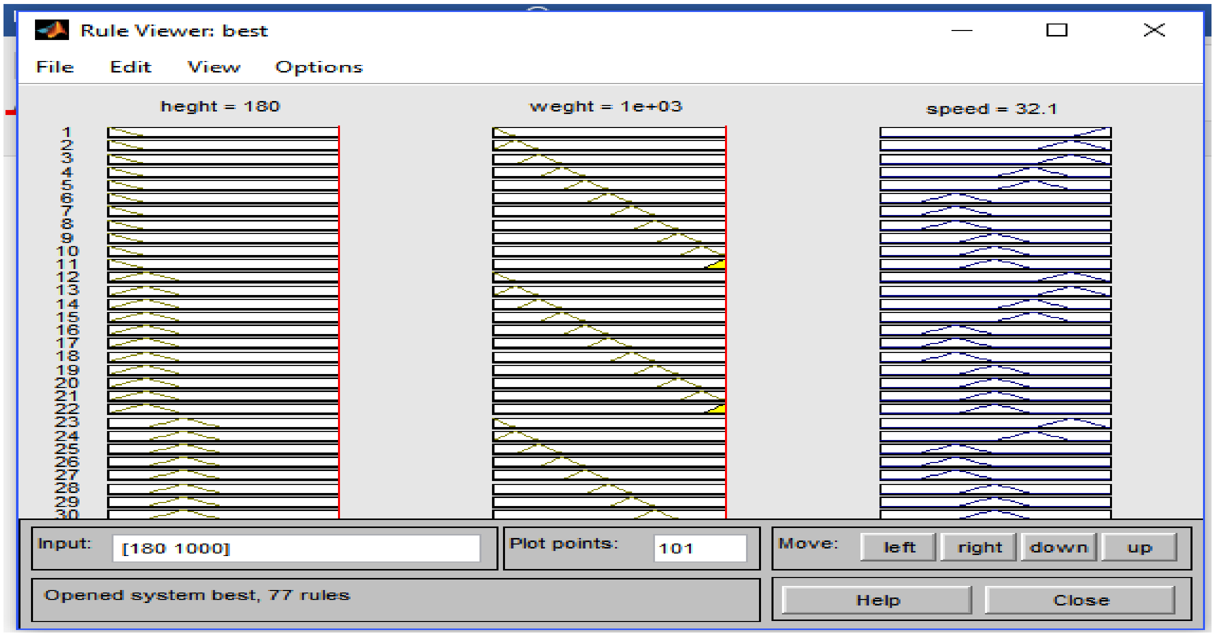
S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	40.8	92.1
2	550(UL)	34.95	78.8
3	600(VL)	23.94	54
4	650 (VL)	24.01	54.2
5	700(L)	24.09	54.3
6	750(JR)	29.72	67
7	800(H)	29.5	66.5
8	850(VH)	29.5	66.5
9	900(EH)	29.26	66
10	950(UH)	18.17	41
11	1000(SH)	29.72	41

S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	35.24	79.4
2	550(UL)	34.95	78.8
3	600(VL)	24.01	54.2
4	650 (VL)	24.09	54.3
5	700(L)	29.72	67
6	750(JR)	29.5	67
7	800(H)	29.26	66
8	850(VH)	18.17	41
9	900(EH)	18.17	41
10	950(UH)	18.17	41
11	1000(SH)	29.72	41

Table4.3: Cane Level in Chute = 120cm (H) and Cane Level in Chute = 150cm (H)

S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	24.01	54.2
2	550(UL)	24.01	54.2
3	600(VL)	24.09	54.3
4	650 (VL)	29.5	66.5
5	700(L)	29.5	66.5
6	750(JR)	29.26	66
7	800(H)	18.17	41
8	850(VH)	18.17	41
9	900(EH)	18.17	41
10	950(UH)	18.17	41
11	1000(SH)	29.72	41

S. No	Cane Weight (Kg)	Speed of Cane carrier (cm/s)	Speed motor in rpm
1	500(SL)	24.26	54.2
2	550(UL)	29.5	54.2
3	600(VL)	29.5	54.3
4	650 (VL)	29.26	66.5
5	700(L)	18.17	66.5
6	750(JR)	18.17	66
7	800(H)	18.17	41
8	850(VH)	18.17	41
9	900(EH)	18.17	41
10	950(UH)	18.17	41
11	1000(SH)	29.72	41

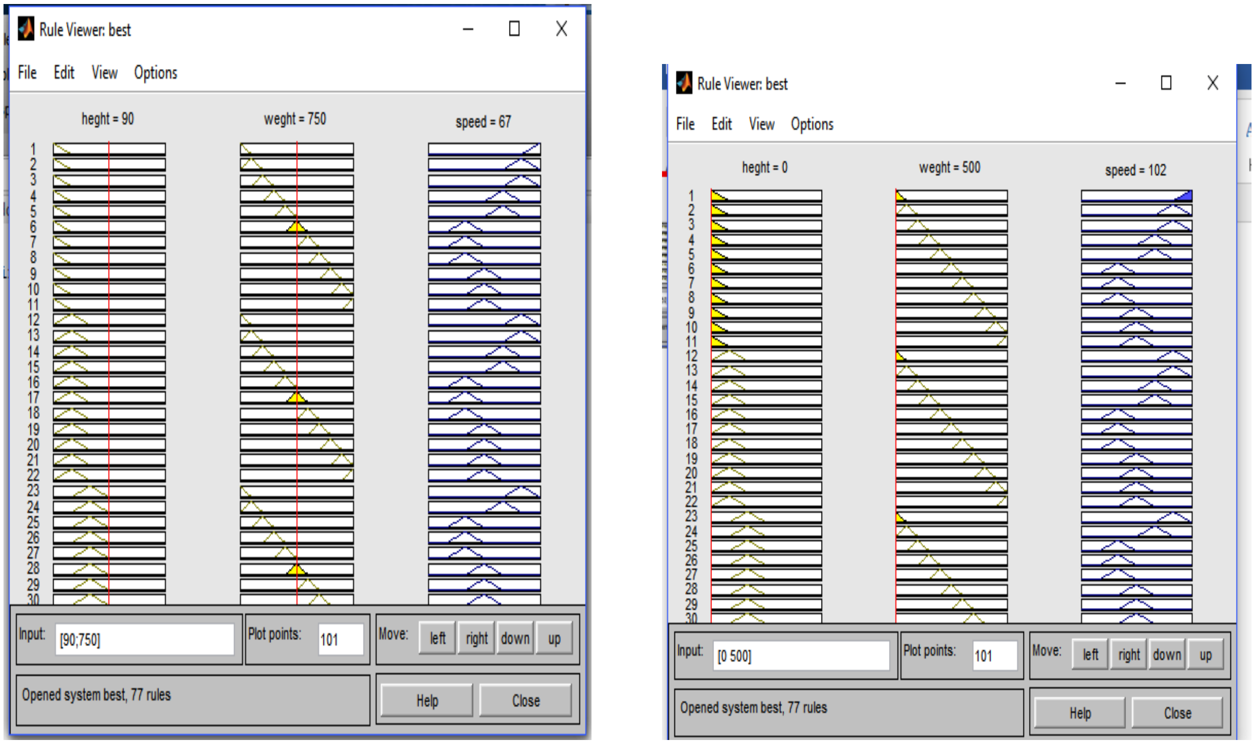


Input: [180 1000]

Plot points: 101

Opened system best, 77 rules

Figure 4.2: Rule viewer with inputs Height=180, input weight 1000 and output speed =32.1rpm



heght = 90 weght = 750 speed = 67

Input: [90;750] Plot points: 101

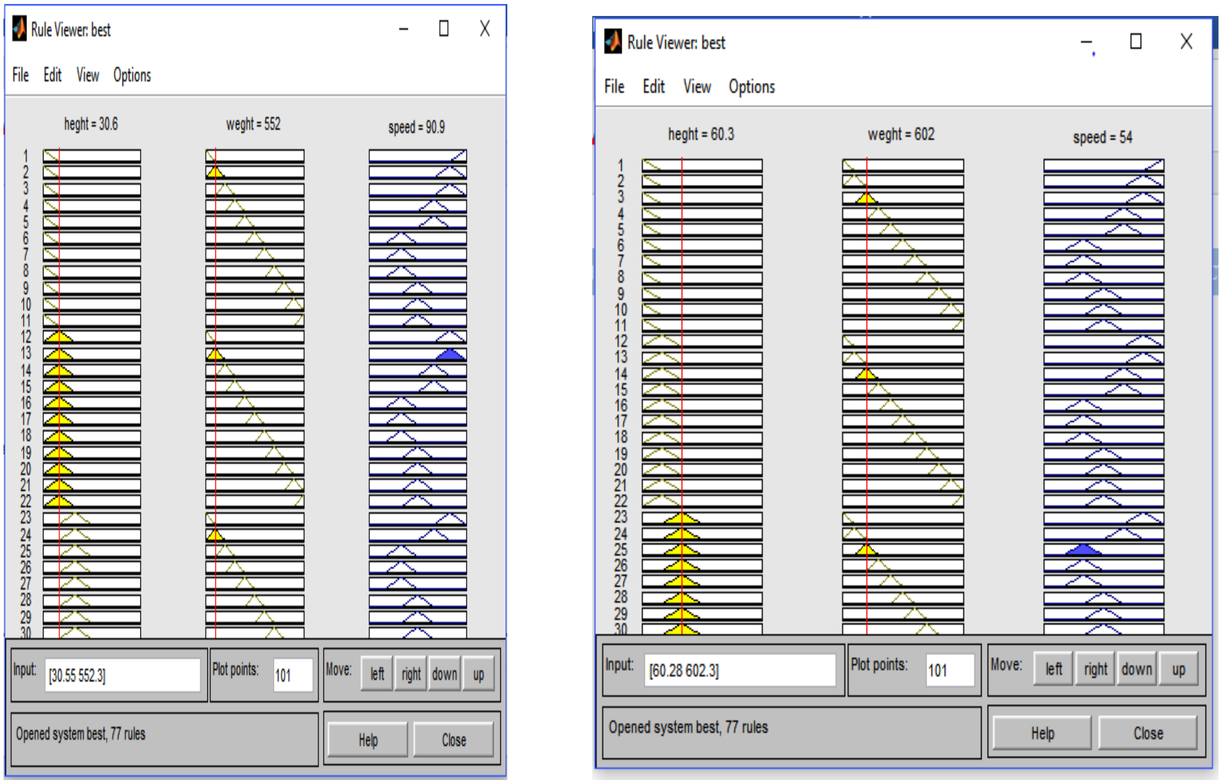
Opened system best, 77 rules

heght = 0 weght = 500 speed = 102

Input: [0 500] Plot points: 101

Opened system best, 77 rules

Figure 4. 3: Rule viewer with inputs Height=90, input weight 750 and output speed =67rpm



heght = 30.6 weght = 552 speed = 90.9

Input: [30.55 552.3] Plot points: 101

Opened system best, 77 rules

heght = 60.3 weght = 602 speed = 54

Input: [60.28 602.3] Plot points: 101

Opened system best, 77 rules

Figure 4. *4*: Rule viewer with inputs Height=30 input weight 550 and output speed =90.6rpm

MATLAB Simulation Result

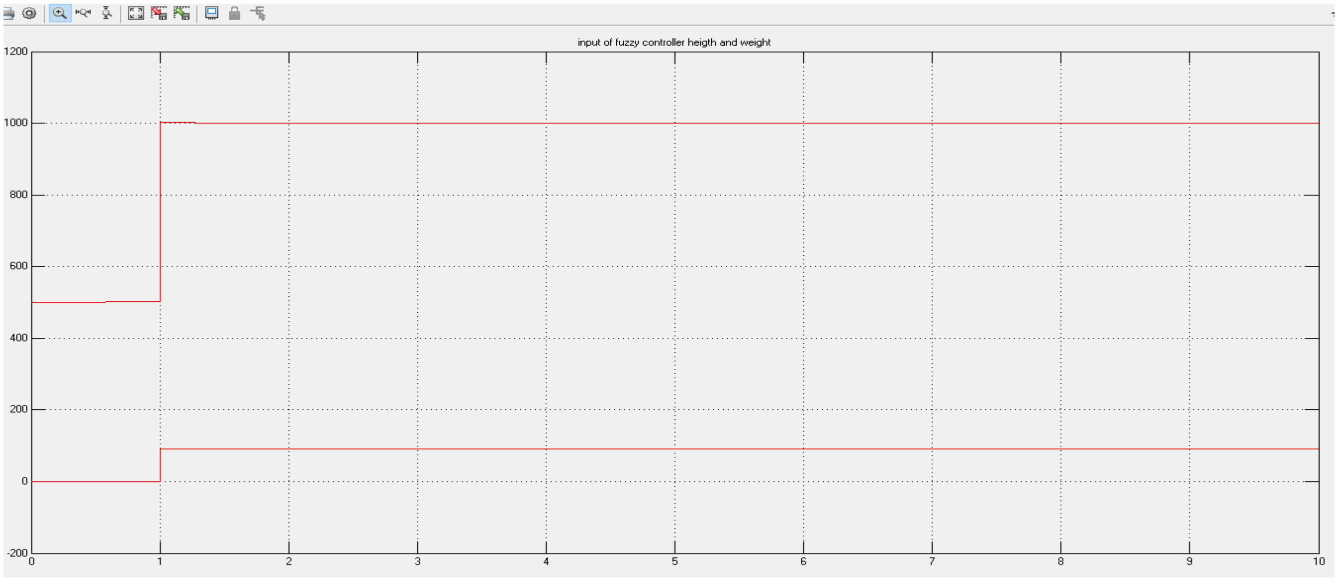


Figure 4. *5*: Height of cane in chute and weight of cane cane in chute

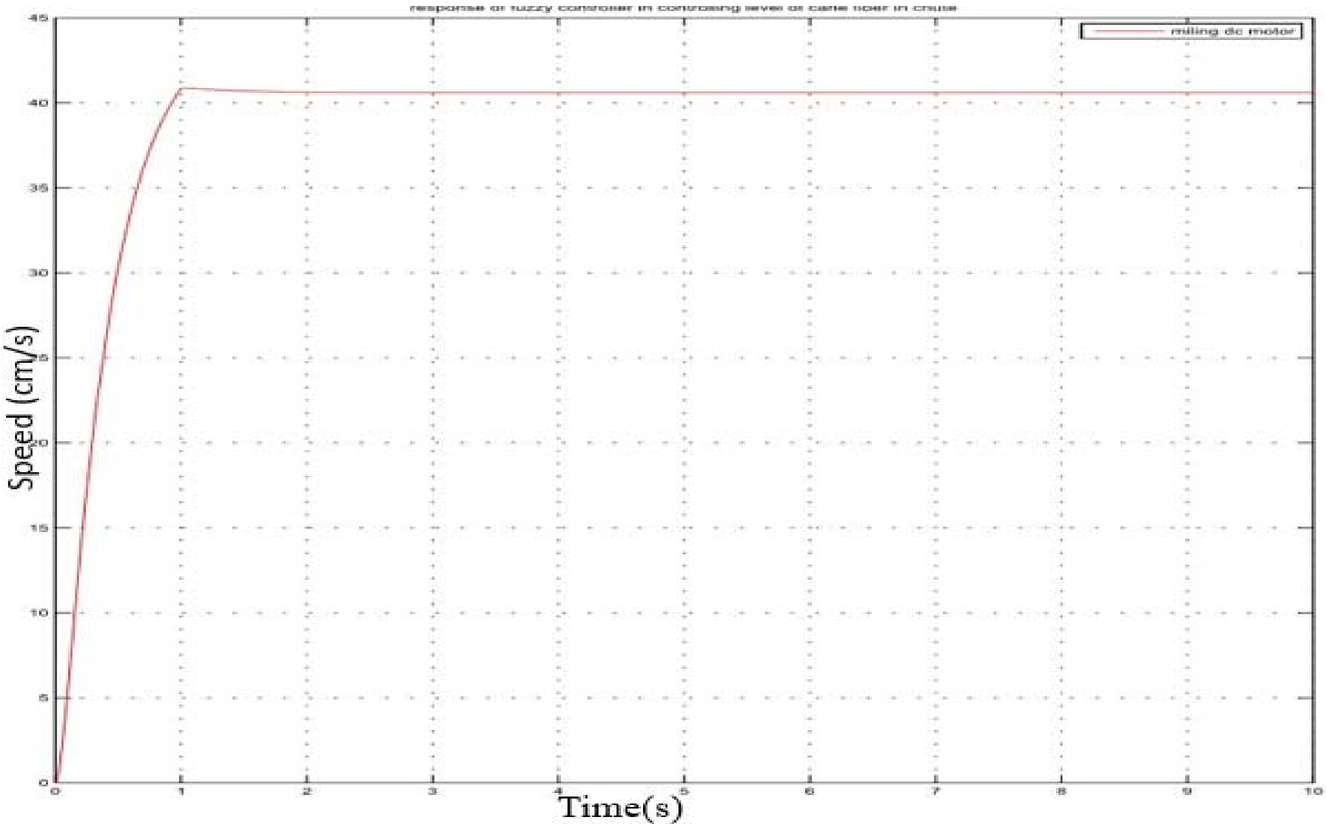


Figure 4. *6*: variation of Speed of rake carrier Motor with respect to time

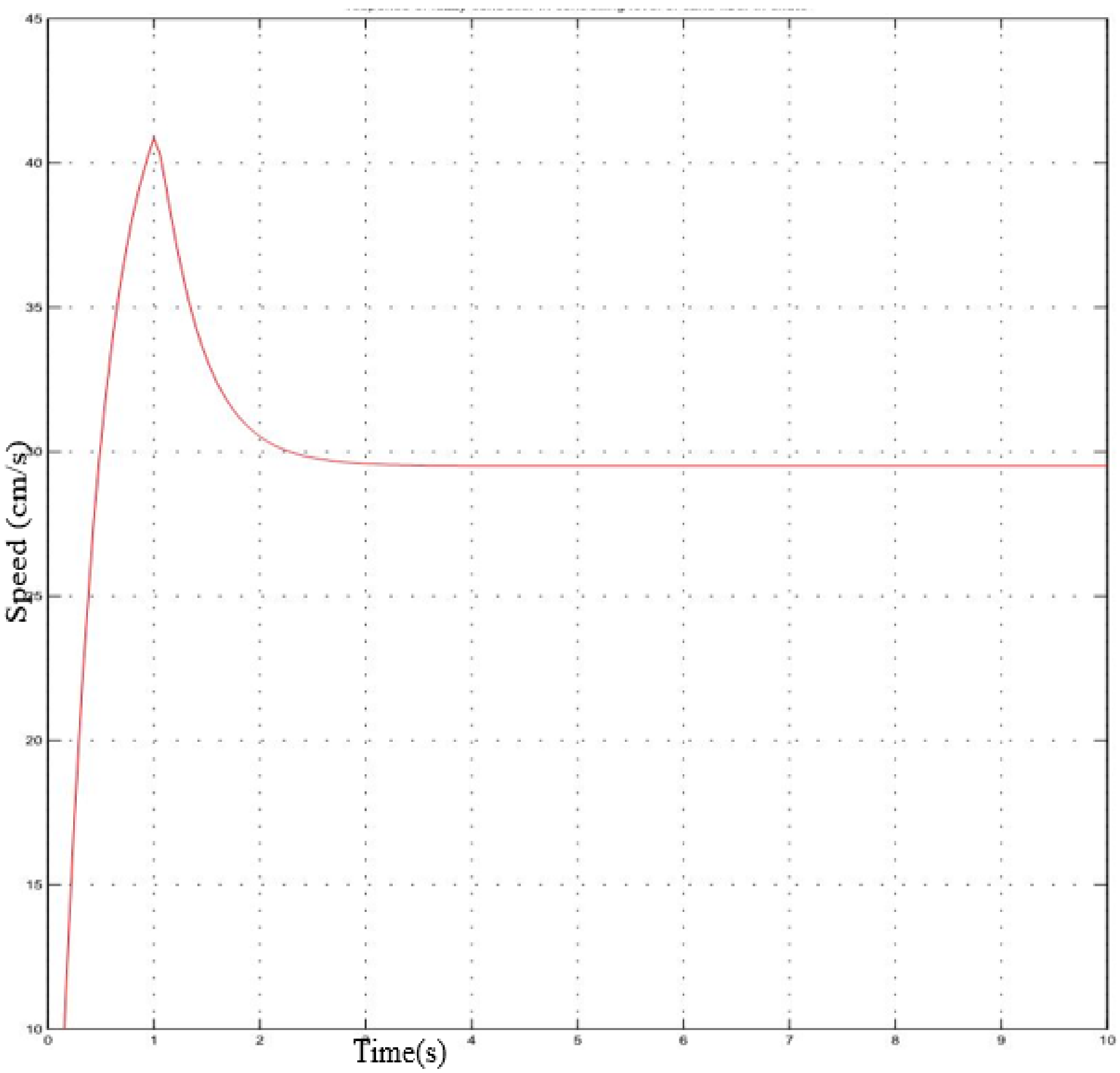


Figure 4.7: speed at which cane carier motor operate just right

CHAPTER FIVE

5. Conclusion and recommendation

This thesis presents the integration of fuzzy controller with cane carrier motor using Simulink block. The performance criteria are defined in time domain where transient response of the system to a step input is considered. The results of this thesis show that the proposed fuzzy controller is able to vary the speed of cane carrier motor depending upon the variation in cane fiber.

A fuzzy controller shows better result in maintaining the cane level at 90cm in chute.and the response has low over shot time, rise time and stead state If the cane level is maintained at 90cm for specified mill parameters which reduce the bagasse failure rate at 0.04 and finally cane juice extraction from the mill will enhanced. The fuzzy control algorithm is based on the operator's experience and field tests. The essence of fuzzy control algorithms is a conditional statement between a fuzzy input variable and a fuzzy output variable

5.1. Recommendation

Even though, Cane level control in chute using fuzzy controller is successfully designed but this system needs some improvement to make this system in high performance and comfortable for all industrial. These are some idea for the future development of this cane level control in chute: design for rake carier that can carry cane more than 500kg and cane height above 180cm is what we recommend and Different strategies like Genetic Algorithm can also be applied for tuning the controller. Also, instead of just fuzzy controller, a Neuro-fuzzy controller can be developed based on this thesis.and also we recommend that instead of using two roller using three rollers is more preferable for increase the process. And implementation what we are recommend here.

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APPENDIX A

The program for designing the Fuzzy Logic Controller using the FIS editor in MATLAB/SIMULINK® is as follows:

- ✓ The program for designing of the Fuzzy Logic Controller is written in a word file.
- ✓ The definitions for all the shown membership functions are written in the program.
- ✓ The 77 rules shown in tabular form in section below are written in the program according to the syntax provided by MATLAB.
- ✓ The document is saved with the extension .fis.

All the 77 If- Then Rules of the Rule Base used for the design of the Fuzzy Logic Controller are as follows

- 1. If (height is extreme low) and (weght is super low) then (speed is ultra_high) (1)
- 2. If (height is extreme low) and (weght is ultra_low) then (speed is extreme high) (1)
- 3. If (height is extreme low) and (weght is extreme_low) then (speed is extreme high) (1)
- 4. If (height is extreme_low) and (weght is very- low) then (speed is very_high) (1)
- 5. If (height is extreme_low) and (weght is low) then (speed is very_high) (1)
- 6. If (height is extreme_low) and (weght is just_right) then (speed is high) (1)
- 7. If (height is extreme_low) and (weght is high) then (speed is high) (1)
- 8. If (height is extreme_low) and (weght is very-_high) then (speed is high) (1)
- 9. If (height is extreme_low) and (weght is extreme high) then (speed is just_right) (1)
- 10. If (height is extreme_low) and (weght is ultra_high) then (speed is just_right) (1)
- 11. If (height is extreme_low) and (weght is Super_High) then (speed is just_right) (1)
- 12. If (height is very low) and (weght is super low) then (speed is extreme high) (1)
- 13. If (height is very low) and (weght is ultra_low) then (speed is extreme high) (1)
- 14. If (height is very low) and (weght is extreme low) then (speed is very_high) (1)
- 15. If (height is very low) and (weght is very low) then (speed is very_high) (1)
- 16. If (height is very low) and (weght is low) then (speed is high) (1)
- 17. If (height is very low) and (weght is just_right) then (speed is high) (1)
- 18. If (height is very low) and (weght is high) then (speed is high) (1)
- 19. If (height is very low) and (weght is very-_high) then (speed is just_right) (1)

- 20. If (height is very low) and (weght is extreme high) then (speed is just_right) (1)
- 21. If (height is very low) and (weght is ultra_high) then (speed is just_right) (1)
- 22. If (height is very low) and (weght is Super_High) then (speed is just_right) (1)
- 23. If (height is low) and (weght is super low) then (speed is extreme high) (1)
- 24. If (height is low) and (weght is ultra_low) then (speed is very_high) (1)
- 25. If (height is low) and (weght is extreme_low) then (speed is high) (1)
- 26. If (height is low) and (weght is very low) then (speed is high) (1)
- 27. If (height is low) and (weght is low) then (speed is high) (1)
- 28. If (height is low) and (weght is just_right) then (speed is just_right) (1)
- 29. If (height is low) and (weght is high) then (speed is just_right) (1)
- 30. If (height is low) and (weght is very-_high) then (speed is just_right) (1)
- 31. If (height is low) and (weght is extreme high) then (speed is just_right) (1)
- 32. If (height is low) and (weght is ultra_high) then (speed is low) (1)
- 33. If (height is low) and (weght is Super_High) then (speed is low) (1)
- 34. If (height is just_right) and (weght is super low) then (speed is very_high) (1)
- 35. If (height is just_right) and (weght is ultra_low) then (speed is very_high) (1)
- 36. If (height is just_right) and (weght is extreme_low) then (speed is high) (1)
- 37. If (height is just_right) and (weght is very low) then (speed is high) (1)
- 38. If (height is just_right) and (weght is low) then (speed is just_right) (1)
- 39. If (height is just_right) and (weght is just_right) then (speed is just_right) (1)
- 40. If (height is just_right) and (weght is high) then (speed is just_right) (1)
- 41. If (height is just_right) and (weght is very-_high) then (speed is low) (1)
- 42. If (height is just_right) and (weght is extreme high) then (speed is low) (1)
- 43. If (height is just_right) and (weght is ultra_high) then (speed is low) (1)
- 44. If (height is just_right) and (weght is Super_High) then (speed is low) (1)
- 45. If (height is high) and (weght is super low) then (speed is high) (1)
- 46. If (height is high) and (weght is ultra_low) then (speed is high) (1)
- 47. If (height is high) and (weght is extreme_low) then (speed is high) (1)
- 48. If (height is high) and (weght is very low) then (speed is just_right) (1)
- 49. If (height is high) and (weght is low) then (speed is just_right) (1)
- 50. If (height is high) and (weght is just_right) then (speed is just_right) (1)

- 51. If (Hight is high) and (weght is high) then (speed is low) (1)
- 52. If (Hight is high) and (weght is very-_high) then (speed is low) (1)
- 53. If (Hight is high) and (weght is extreme high) then (speed is low) (1)
- 54. If (Hight is high) and (weght is ultra_high) then (speed is low) (1)
- 55. If (Hight is high) and (weght is Super_High) then (speed is low) (1)
- 56. If (Hight is very_high) and (weght is super low) then (speed is high) (1)
- 57. If (Hight is very_high) and (weght is ultra_low) then (speed is just_right) (1)
- 58. If (height is very_high) and (weght is extreme_low) then (speed is just_right) (1)
- 59. If (height is very_high) and (weght is very low) then (speed is just_right) (1)
- 60. If (height is very_high) and (weght is low) then (speed is low) (1)
- 61. If (height is very_high) and (weght is just_right) then (speed is low) (1)
- 62. If (height is very_high) and (weght is high) then (speed is low) (1)
- 63. If (height is very_high) and (weght is very-_high) then (speed is low) (1)
- 64. If (height is very_high) and (weght is extreme high) then (speed is low) (1)
- 65. If (height is very_high) and (weght is ultra_high) then (speed is low) (1)
- 66. If (height is very_high) and (weght is Super_High) then (speed is Very Low) (1)
- 67. If (height is extreme high) and (weght is super low) then (speed is just_right) (1)
- 68. If (height is extreme high) and (weght is ultra_low) then (speed is just_right) (1)
- 69. If (height is extreme high) and (weght is extreme_low) then (speed is low) (1)
- 70. If (height is extreme high) and (weght is very low) then (speed is low) (1)
- 71. If (height is extreme high) and (weght is low) then (speed is low) (1)
- 72. If (height is extreme high) and (weght is just_right) then (speed is low) (1)
- 73. If (height is extreme high) and (weght is high) then (speed is low) (1)
- 74. If (height is extreme high) and (weght is very-_high) then (speed is Very Low) (1)
- 75. If (height is extreme high) and (weght is extreme high) then (speed is Very Low) (1)
- 76. If (height is extreme high) and (weght is ultra_high) then (speed is Very Low) (1)
- 77. If (height is extreme high) and (weght is Super_High) then (speed is Very Low) (1)