MOISTURE CONTROL IN FIBER BOARD MANUFACTURING

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
in partial fulfillment of the requirements for the
degree of Master of Science

by

THUSHARA UDAKANDAGE

Supervised by

Dr. Rohan Munasingha
Dr. Sisil Kumarawadu

Department of Electrical Engineering
University of Moratuwa, Sri Lanka

December 2008

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

Thushara Udakandage
Date: 19th December 2008

We/I endorse the declaration by the candidate.

UOM Verified Signature ***UOM Verified Signature***

Dr. Rohan Munasingha Dr. Sisil Kumarawadu

Dr. Rohan Munasinghe
Senior Lecturer
Dept. of Electronic and
Telecommunication Engineering
University of Moratuwa.

CONTENTS

Declaration i
Contents ii
Abstract iv
Acknowledgement v
List of Figures vi
List of Principal Symbols vii
1. Introduction 1
1.1 The Process of Moisture Control 3
1.2 The Idea of Automatic Control 7
2. Theoretical Development 9
2.1 The Constitutive Equations of Heat Transfer 9
2.1.1 The Conduction 10
2.1.2 The Convection 10
2.1.3 The Heat Transfer due to Flow 10
2.2 The River Analogy 11
2.3 Heat Model of the river 12
2.4 The Dryer 13
2.5 Heat Model of the Dryer 13
2.6 The Key 17
3. The Controller 19
3.1 The Cascaded PID 19
3.1.1 The PID equation 20
3.1.2 Control Mode 21
3.1.3 Tuning the PID Gains 22
3.2 The Multistage Controller 22
3.2.1 The Blow Valve 24
3.2.2 The Feed Screw Speed 25
3.2.3 The Differential Pressure 25
3.2.4 Experimental Data 29
3.2.5 The Experimental Data Plot obtained for Blow Valve 30
3.2.6 The Experimental Data Plot obtained for Feed Screw Speed 34
3.2.7 The Experimental Data Plot obtained for Differential Pressure 37
3.3 The Model for the Temperature Difference 40
3.4 The Algorithm 45
4. Application & Results 48
4.1 Tuning the PIDs 49
4.2 The Results 52
5. Conclusion 56

References **58**
Appendix A Additional Relationships 59
Appendix B Program of the cascaded PID 60

Abstract

In fiber board industry, the moisture content (the moisture level) of fiber, perhaps the most critical parameter of fiber board manufacturing, works as the medium of heat transfer across the fiber mat while subjected to pressing in the hot press. The high moisture content splits (delaminates) the wood panel when decompressing due to the release of high steam pressure develops inside it where as the low moisture content split the panel as a result of low heat transfer causing a low level curing of resin inside the panel.

So controlling moisture is the most critical issue of the wood refiner operators which is a highly skill job that cannot be easily absorbed until having long time practice on it.

The fiber moisture content is controlled inside the dryer by adjusting the dryer outlet temperature set point. This set point is automatically maintained by the valve position of the steam PRV (Pressure Regulating Valve) of the heat exchanger, the only energy source of the dryer. In very cool climate conditions the air and the environment get cold where the dryer outlet temperature cannot reach the required set point even though the PRV is at its 100% open condition. In 100% valve open condition the system is supplied with maximum heat energy that can be given and the only way to further increase the outlet temperature is to make a change in the process. This change is done by using three parameters namely the blow valve position, the refiner feed screw speed and the differential pressure.

The mistakes in putting the correct set points and forgetting to put it on right time are human errors usually happen. This makes a heavy loss in the profit and restricts the consistency of the process.

To avoid this problem, the process of controlling moisture is fully automated with the four parameters mentioned, using a cascaded PID system coupled with a multistage controller. The cascaded PID takes moisture as the reference set point that controls the outlet temperature and this in turn controls the steam PRV. At the time when the PRV is at 100% open position the other three parameters work together as a multi stage controller in increasing the outlet temperature.

Acknowledgement

Thanks are due first to my supervisors, Dr. Rohan Munasingha and Dr. Sisil Kumarawadu for their great insights, perspectives, guidance and sense of humor. My sincere gratitude is extended to the course coordinators Dr. Lanka Udawatta and Dr. Nanayakkara and to the former Head of the Department of Electrical Engineering Prof. Ranjith Perera for giving me the opportunity to make this a reality.

And also I would like to extend my sincere gratitude to Prof. Lucas, Prof. Karunadasa and Dr. Wickramarachchi for the ideas, advices and encouragements focused on my work.

At the same time I would extend my sincere gratitude to Dr. Koliya Pulasingha of SLIIT for being an enormous force behind my educational development and for the continuous encouragement.

My sincere thanks also go to the officers in Post Graduate Studies, Faculty of Engineering, The University of Moratuwa, Sri Lanka for helping in various ways to clarify the things related to my academic works in time with excellent cooperation and guidance. Sincere gratitude is also extended to the people who serve in the Department of Electrical Engineering office.

I would like to extend my sincere gratitude to the Management of Merbok MDF Lanka for appreciating and providing me the time and space to carry out the research and application. My special thanks will go to the operators of the refiner for the great help given to me in the development of the project.

Lastly, I should thank many individuals, friends and colleagues who have not been mentioned here personally in making this educational process a success. Perhaps it would not be a success without the great help of them.

List of Figures

Figure	Page
1.1 The Dryer	3
1.2 The Manual Moisture control	4
1.3 The outlet temperature PID	5
1.4 The Process of moisture control	6
1.5 The Differential Pressure	7
2.1 Fully insulated River	11
2.2 River subjected to flow of logs	11
2.3 Fully insulated Dryer	13
2.4 Fiber flow into the Dryer	14
3.1 The Cascade PID	20
3.2 The Differential Pressure PID	26
3.3 The Outlet temperature plot against blow valve	30
3.4 The plot of $\log_{10}[y(\infty) - y]$ against B_V	32
3.5 Theoretical and Experimental plot of outlet temperature against blow valve	33
3.6 The outlet temperature plot against feed screw	34
3.7 The plot of $\log_{10}[y(\infty) - y]$ against RPM_{FS}	35
3.8 Theoretical and Experimental plot of outlet temperature against Feed Screw RPM	36
3.9 The outlet temperature plot against differential pressure	37
3.10 The plot of $\log_{10}[y(\infty) - y]$ against P_{diff}	38
3.11 Theoretical and Experimental plot of outlet temperature against Differential pressure	39
3.12 Relationship between fees screw speed and main motor current	44
3.13 The block diagram of the control system	45
4.1 The Moisture PID, the first PID of the cascaded PID	49
4.2 The Outlet Temperature PID, the second PID of the cascaded PID	50
4.3 The Cascaded PID. The moisture and the outlet temperature PIDs are cascaded	51
4.4 The popup screen of PID. The background is the refiner main screen	52
4.5 Outlet temperature, Outlet temperature set point, PRV position against time (Minutes)	53
4.6 The response of Moisture and the Moisture set point against time (Minutes)	53
4.7 Table of data of a general situation of moisture control	54

List of Principle Symbols

B_{Valve}	The Blow Valve Position
RPM_{FS}	The Refiner Feed Screw Speed in RPM
P_{diff}	The Differential Pressure
T_{outlet}	The outlet temperature of Air (Dryer outlet temperature)
$T_{outlet}^{100\%}$	The outlet temperature of Air when the steam PRV is at 100% open condition
T_{inlet}	The inlet temperature of Air (Dryer inlet temperature)
$\Delta T_{B_{Valve}}$	The outlet temperature difference due to Blow Valve
$\Delta T_{(RPM_{FS})}$	The outlet temperature difference due to Feed Screw Speed
$\Delta T_{P_{diff}}$	The outlet temperature difference due to Differential Pressure
w_{fiber}	Mass flow rate of fiber coming into the dryer
l_{fiber}	Average length of a fiber
A_{fiber}	Total area of fiber
PRV	Pressure Regulating Valve

Chapter 1

Introduction

Fiber boards are manufactured using wood fibers which are created by grinding wood chips. Wood chips can be grinded in between the grinding plates which are constituted in the wood refiners. In wood refiners these grinding plates are fixed in a certain way that one disk is stationary while the other is rotating maintaining a very small gap in between them. The average gap size is around 1mm to 2mm and this can be adjusted to alter the size of the fibers which are generated. The size of the fiber can be decided by the technical assurance department and the refiner operators have to fulfill the requirement. The chips are subjected to wash before coming into the digester column and then subjected to a high steam pressure inside the digester column. In the digester column a wood chip may stay around 2 minutes to be cooked inside it. The cooking time is also adjusted by changing the chip level of the column. The cooking process makes it easy for the refiner plates to grind the chips. The absorption of steam softens the wood chips.

However this absorption of water by the wood chips at washing and steaming under high pressure inside the digester column and then after application of resins, wax and other liquid chemicals results in creating very wet fibers inside the plate chamber. The wet fibers are like a pulp with full of water where the most of water has to be removed before going into the production line. Even though water is removed from the fibers, a certain amount of water or moisture has to be remained within them to make the fiber mat enable to conduct heat through it.

In the production line, the fibers are formed as a mat with certain amount of weight and height according to the specifications set by the thickness of the board which has to be manufactured. Then the fiber board is made by pressing the resin coated fiber mat inside a Press. The press platens are heated so as to supply heat to the fiber mat while pressing. Since the wood is a good insulator this transferring of heat would not happen unless it has moisture as a medium of heat transfer.

So it has to be convinced that the control of moisture content of fiber is very crucial since it works as the medium for this valuable phenomenon of transferring heat energy across the fiber panel.

In the press the fiber mats are subjected to a very high pressure and a high temperature level which is around 11,300 tons and 185^0C, for a certain period of time (cycle time) set by the recipe of the board that has to be produced. Under this condition of high pressure and high temperature, an intense pressure is built inside the pressing board from the steam generated by the heated moisture. This steam pressure creates a huge force that acts against the chemical bonds created among each and every fiber as a result of the resin reaction. If the moisture content is within the specification it can be guaranteed that this force would be counter balanced by the chemical bonds. But if the moisture content is high the board gets split at the press, breaking this equilibrium.

In case of low moisture condition the same splitting condition creates as a result of poor conduction of heat across the board. The amount of moisture inside the fiber panel is not sufficient to transfer enough heat that can complete the resin curing process.

The preferred moisture level (content) has to be determined with some experience in fiber board production. According to some literature on fiber board manufacturing the average moisture level that is recommended is 10%. But this is of course relative to the place where the plant is situated. It all depends on the humidity of atmosphere, environment temperature, raining frequency and so many other parameters. But once the appropriate moisture level is determined with the experience we only need to maintain it.

Maintaining the moisture or controlling the moisture content is the most critical issue of the wood refiner operators which is a highly skill job that cannot be easily absorbed until having long time practice on it. The other issue is, even though the operators become well experienced in doing this, under extreme situations like in a breakdown or in any other emergency situation they become unaware of it, may be for a short time, making the moisture level goes totally out of range. Once it has deviated considerably away from the required level (the set point) the time it takes to bring it back would be reasonably high depend on the condition, putting the whole process into a totally undesirable stage.

The most unpleasant situation arises when the moisture content goes high passing the set point where as the lowering of moisture content of fiber from the required set point is also a serious problem. When the boards get start splitting, it continues for a long time depends on the amount of moisture that has increased, until it comes to normal.

The statistics of the damaged boards due to high moisture splitting in Merbok MDF Lanka can be shown as follows (Merbok is a 24 hour running factory which is shut down only for maintenance programs);

The average production of a day ≈ 400 m^3
The average amount of boards get split in a day ≈ 4 m^3 (1% of the daily avg. production)
Cost per one cubic meter of boards = Rs. 28,000.00
Average cost of damaged boards per day ≈ 4 x 28,000 = Rs. 112,000.00
Average cost of damaged boards per month ≈ 27 x 112,000 = Rs. 3,024,000.00
(If we assume that the plant has to be stopped at least 3 days in a month due to shut downs and other break downs)
The amounts calculated here are only in the sense of cost of boards. But the damage happens to the consistency of the production and downtime costs have not been considered here. Normally Merbok MDF Lanka, the plant taken into consideration has a production cost of around Rs. 8000/minute. So if the plant gets a down time of around ten minutes for removing any split board that cannot be removed by the board reject mechanism, the cost of downtime would be Rs. 80,000.00 without any sense. Normally in Merbok it is always more than 10 minutes.

So the average cost of damage per month due to splitting > Rs. 6,000,000.00 (six million rupees)
In Merbok this amount is exactly equal to the amount paid for entire staff salary.

1.1 The Process of Moisture Control

Normally the moisture is controlled by refiner operators by controlling the dryer outlet temperature. It was understood by long time practice that dryer outlet temperature and moisture content of fiber has a linear relationship (**See Appendix A**).
What really happens in the dryer control is that the outlet temperature set point determines the open percentage of the steam PRV of the heat exchanger of the dryer (see figure 1.1).

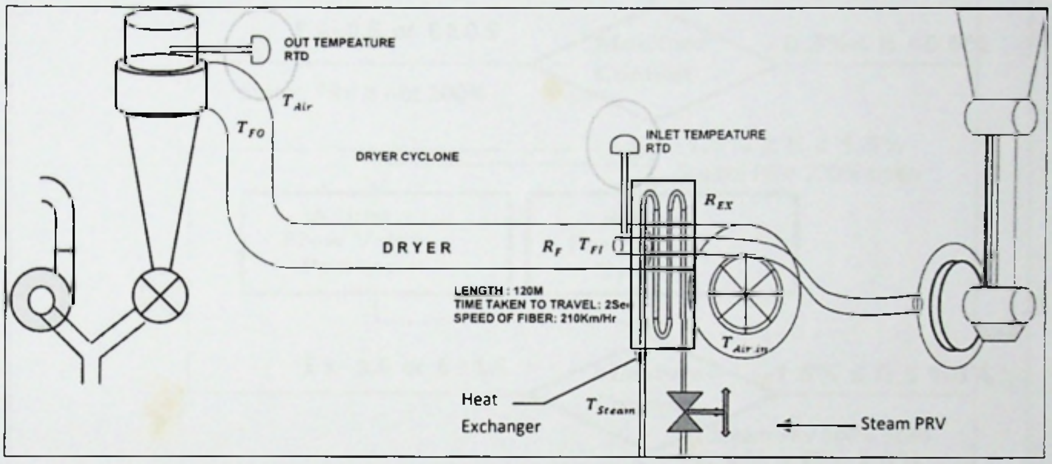


Figure 1.1 The Dryer, the Heat Exchanger and the Steam PRV along with refiner

The PRV is controlled by the analog control output of the outlet temperature PID. In the outlet temperature PID the operator sets the outlet temperature set-point suitable for getting the appropriate moisture level. The moisture level and the outlet temperature have a known relationship **(See Appendix A)**.
The operator has to observe the value of the moisture content continuously whose analog signal is taken to the SCADA via the PLC, to keep it in a fix value requested by the press operator or the production department. Due to the changes happen in the outlet temperature process variable or in other words the actual outlet temperature value, the value of moisture content changes. When the change goes more than 1% away from the desired value the system becomes uncontrollable.
The refiner operator always tries to keep the moisture content in between ± 0.5 from the reference point (ex. If the reference level is 7.5% moisture, then he would keep it in between 7.0% and 8.0%). To keep this in a fix value the operator has to keep looking at the moisture value on his HMI. The way of controlling moisture by the operator can be explained with the aid of the flow chart in figure 1.2.

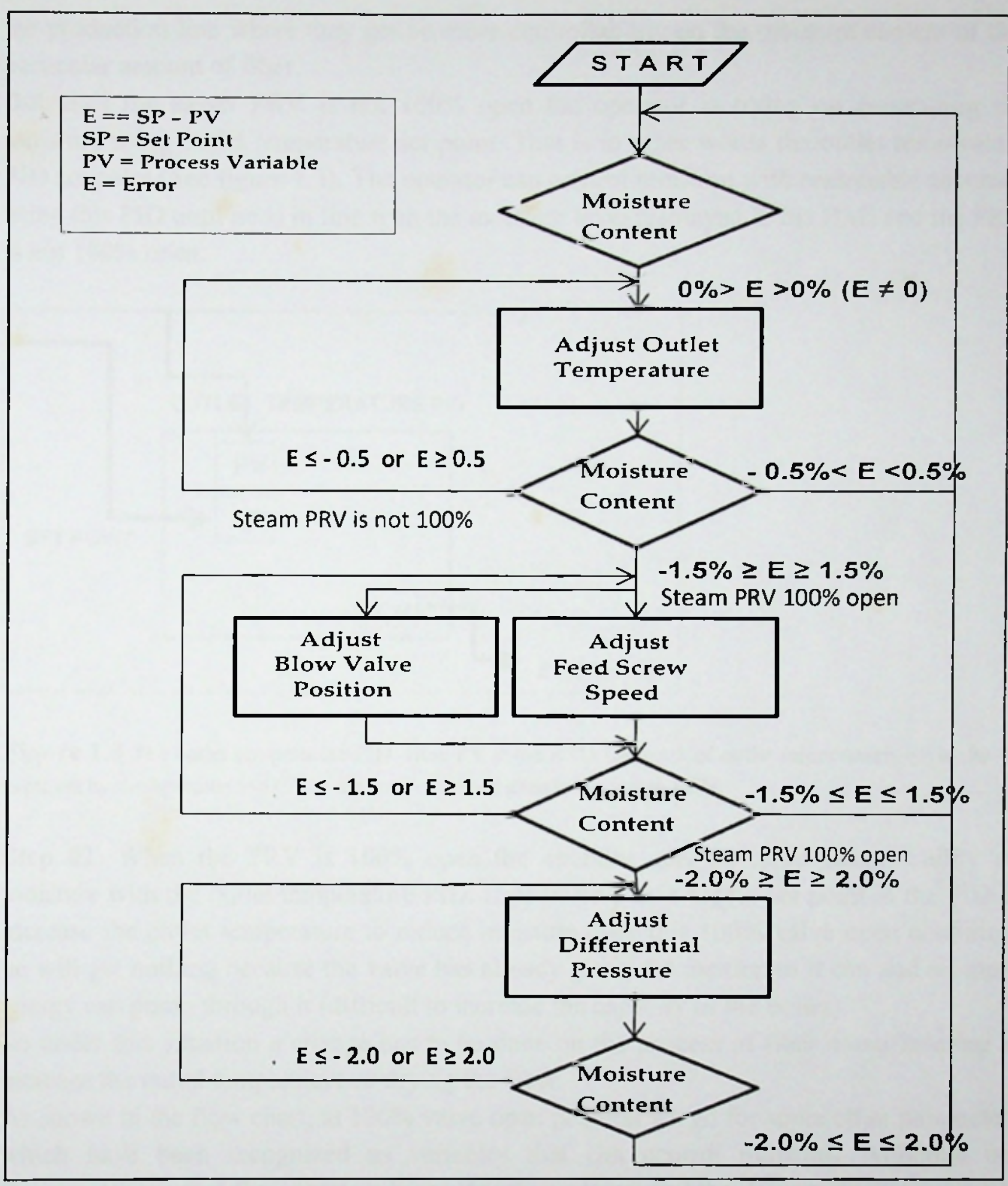


Figure 1.2 The manual control of moisture by the refiner operators.

Step 01: It can be seen from the flow chart as the first step, the operator tries to control moisture by adjusting the outlet temperature PID set point where he can control the steam PRV position. Until the steam PRV is not 100% open the operator keep trying control the moisture only by setting the outlet temperature. If the moisture content is within the region of interest he make no changes in the system but keep observing the moister feedback in his HMI.

In the event the moisture content goes away from the range of interest as a result of forgetting or getting no chance to concentrate on it, high or low moisture fiber comes to the production line where they get no more controllability on the moisture content of this particular amount of fiber.

But until the steam PRV is not 100% open the operator is trying on controlling the moisture using outlet temperature set point. That is in other words the outlet temperature PID set point (See figure 1.3). The operator can control moisture with reasonable accuracy using this PID until he is in line with the moisture level displayed in his HMI and the PRV is not 100% open.

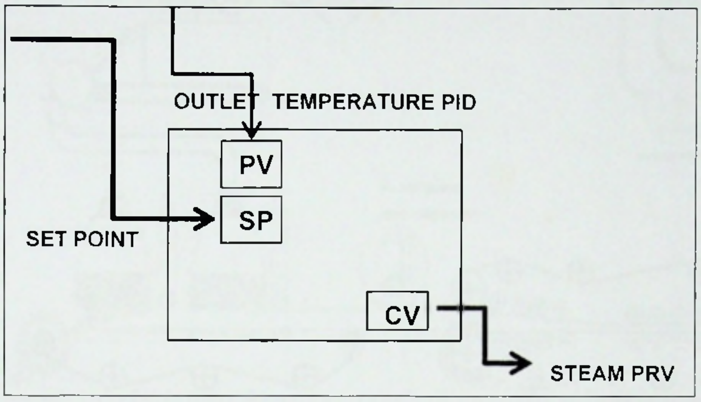


Figure 1.3 The outlet temperature PID. Here PV is the RTD feedback of outlet temperature. SP is the set point set by the operator and CV is the control output goes to the steam PRV.

Step 02: When the PRV is 100% open the operator gets no more controllability on moisture with the outlet temperature PID. If operator puts a higher set point in the PID to increase the outlet temperature to reduce moisture after this 100% valve open condition, he will get nothing because the valve has already given the maximum it can and no more energy can pump through it (difficult to increase the capacity of the boiler).

So under this situation a change has to be done on the process of fiber manufacturing to increase the outlet temperature or drying the fiber.

As shown in the flow chart, at 100% valve open position we go for some other parameters which have been recognized as variables that can control moisture. Although not theoretically proved the operators know that they can control the dryer temperature and in turn the moisture content by manipulating these parameters.

In this step they adjust the blow valve position and feed screw speed to increase the dryer outlet temperature. To increase the temperature, first they close the blow valve by a known small amount. Normally this amount is around 10% of full valve open position. Then a step response can be monitored at the outlet temperature. If this increment of outlet temperature can bring down the moisture to his requirement he would not go for any other parameter change. Because closing the blow valve by a small amount will not result in a reduction of fiber output or the production. Figure 3.3 shows response of outlet temperature for the change in blow valve position.

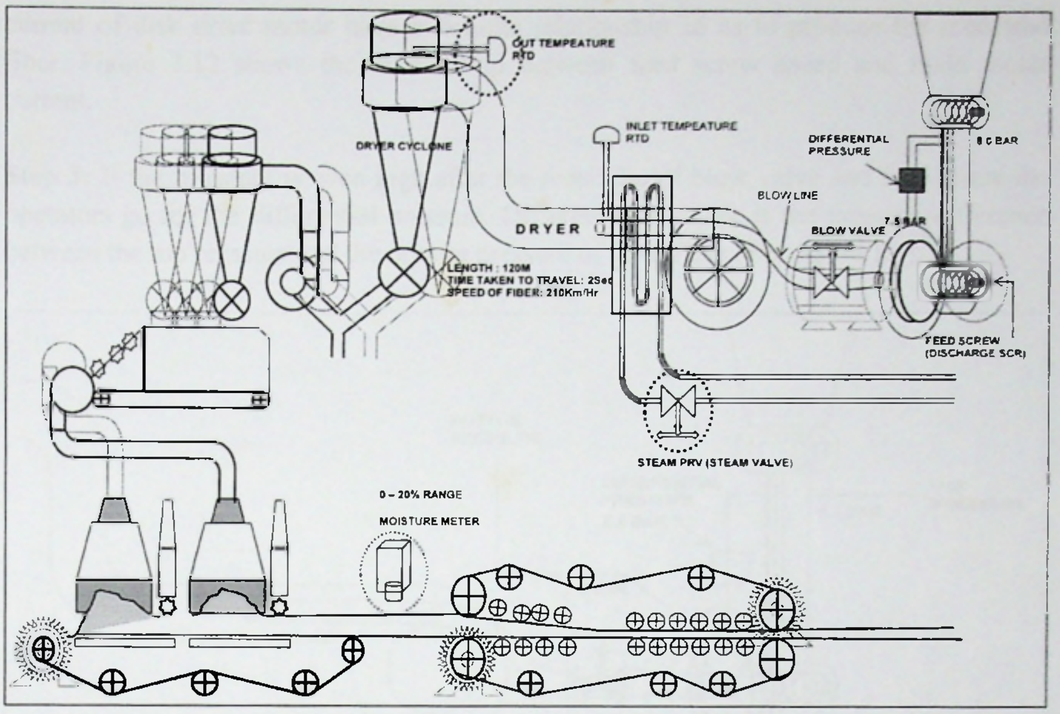


Figure 1.4 The process of moisture control using four parameters with moisture meter and outlet temperature feed backs. The four parameters: The steam PRV position, the blow valve position, the feed screw speed and the differential pressure set point.

If the increment of outlet temperature is not sufficient to bring down the moisture the operator would then go for the feed screw speed (RPM). Any change in the feed screw speed highly reflects at the outlet temperature values. The reduction of feed screw speed reduces the mass flow and the reduction of mass flow rate reduces the heat absorption from air. It is the heat of the air that counts the increment of outlet temperature. Outlet temperature is actually the Air outlet temperature because the outlet RTD touches only the air. The relationships of these parameters have already been derived and will be explained in later chapters.

When closing the blow valve it actually creates a high pressure inside the disk chamber. This pressure actually results in an increment in the amperage of disk drive motor (Main Motor). Actually the main motor current has to be increased with the speed of the feed screw. Increasing the feed screw speed increase the mass flow rate through the rotating disks and this increment of mass increase the friction on disks advancing the load applied to the motor. This actually happens when the operator tries to make the same size of fibers at different speed levels. When more mass comes into the disks the gap between the disks starts to increase. If we let it increase then the motor current can go down. But when the gap is increased the size of the fiber becomes larger and becomes out of specification. So to maintain the same size in fiber we have to increase the load applied to the fiber by the disks. This load results in an increment of the friction against the motion of disk drive motor. This friction raises the main motor current. The speed of the feed screw and the current of disk drive motor have a definite relationship so as to produce the requested fiber. Figure 3.12 shows the relationship between feed screw speed and main motor current.

Step 3: If the moisture is even high after the reduction of blow valve and feed screw the operators go for the differential pressure. Differential pressure is the pressure difference between the top pressure and the bottom pressure of the refiner (See figure 1.5).

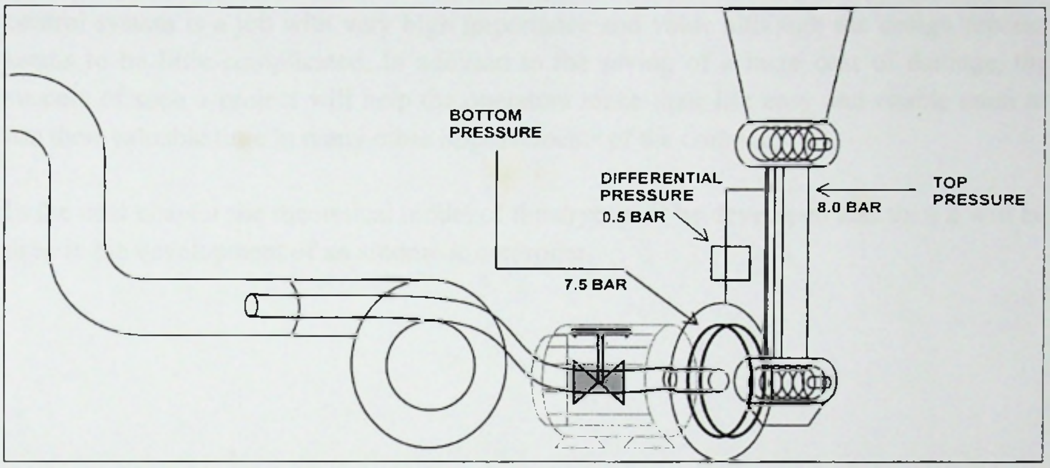


Figure 1.5 Differential pressure is difference between top pressure and bottom pressure.

Here the differential pressure is controlled by setting the set point of the differential pressure PID.

Differential pressure = Top pressure – Bottom pressure

The operator can set the top pressure set point and differential pressure set point. These two automatically decides the bottom pressure. The bottom pressure doesn't have a PID for its control and it is the differential pressure PID that controls the bottom pressure using the top pressure PID.

When the differential pressure is positive, the bottom pressure is lower than the top pressure. And when the differential pressure is negative, the bottom pressure becomes greater than the top pressure. In this negative situation flow of mass from top to bottom is damped. The damping or the reverse tendency of flow reduces the mass flow rate which results in an increment of outlet temperature of the dryer.

1.2 The idea of Automatic Control

The operators usually follow the above procedure for controlling moisture. Actually this can be done without any problem if not for the human errors. When doing the same thing for a long time continuously the human behavior likes to get rid of it. Human errors are usual in every operator oriented tasks. There are ways that human errors can be minimized. One way of doing that is shortening the duration of the shift of operators.

Working more than 8 hours will give very bad results. But in some cases even 8 hours duty may be too long.

However the need of fully automatic systems for industrial purposes is getting increased due to this problem and due to so many other important reasons. The speed and precision with long lasting consistency can only be achieved through automatic systems.

The conversion of manual moisture control procedure into a fully automatic moisture control system is a job with very high importance and value although the design process seems to be little complicated. In addition to the saving of a huge cost of damage, the success of such a project will help the operators make their life easy and enable them to use their valuable time in many other improvements of the company.

In the next chapter the theoretical model of the dryer will be developed and then it will be used in the development of an automatic controller.

Chapter 2

Theoretical Development

In the theoretical development the dryer has to be modeled first in order to understand the problem with thorough understanding. The whole process is a heat application and the constitutive equations of heat transfer have to be hired in solving and understanding this.

2.1 The Constitutive Equations of Heat Transfer.

The constitutive equations of thermal systems have to be taken into consideration for getting a more theoretical understanding of the existing system.

The net heat flow (Q) is equal to the rate of change (increase) of thermal energy and the associated constitutive relation is [1];

$$\sum Q_i = \rho V c \frac{dT}{dt}$$

where $\boldsymbol{\rho V c}$ is assumed constant, so can write this as [1];

$$Q = C_h \frac{dT}{dt}$$

Here $C_h = \rho V c = mc$ = thermal capacitance. $\boldsymbol{c}$ is the specific heat of the object and V is the volume. ρ = density and $\rho V = mass$.

This can be rewrite as [2], [1];

$$\dot{T} = \frac{1}{C_h} Q$$

There are three ways that heat can be transferred from one place to another place depending on the temperature difference between each other.

- Conduction
- Convection
- Radiation

In the case of our interest transfer due to radiation will not be considered since the materials in the system touch each other. In addition to the other two ways our system allow heat flow due to the flow of cool mass into a warm mass where the relationship takes little different from the above equations explaining the above two ways of heat transfer. Let us state the constitutive relationships that describe the heat flow excluding the relationship for radiation since it is not in the consideration.

2.1.1 The Conduction

Heat energy (q) flows through substances or transfer though substances at a rate proportional to the temperature difference between substances. Here in this situation the heat of air is transferred to fibers though the convection [2], [1]. R = **Thermal Resistance**

$$q = \frac{1}{R}(T_1 - T_2) \qquad 2.1$$

Here,

$$\frac{1}{R} = \frac{kA}{l} \qquad 2.2$$

Where, A is the area of the heat transfer element and l is the length of the heat transferring element. k = Thermal Conductivity.

2.1.2 The Convection

In convection, the heat (q) transfer takes place by the physical movement of the heat-carrying particles in the medium [1];

$$q = h_c A(T_1 - T_2) \qquad 2.3$$

Here $\mathbf{h_c}$ is the Convection Heat Transfer Coefficient and **A** is the area of through which the heat transfers. Here A will be once the area of fiber and once the area of the steam coil in our system.

In addition to the above two methods the following relationship shows the equation for the flow of heat as a result of cool mass flow into a reservoir of warm mass.

2.1.3 The Heat Transfer due to Flow.

Heat (q) transfers as a result of cool mass flow into warmer mass and vice versa [2];

$$q = wc_v(T_1 - T_2) \qquad 2.4$$

Here,

w = **Mass flow rate** of fluid at T_1 flowing into the reservoir at T_2.

c_v = **Specific heat** at constant volume.

These equations will be used in the modeling of dryer.

2.2 The River Analogy

For a better understanding of the dryer, it is going to be compared with a ideal river which is totally straight, having no heat loss except a uniform heat loss from the top along the river.

Let us consider a uniform and straight portion of the river. And assume that this river is heated somewhat far away from the portion. In the first step it is assumed that the river has no heat loss while flowing. Two RTDs are fixed at the end point of the portion to measure the inlet and outlet temperature of water.

So if there is no any heat loss the inlet temperature and the outlet temperature would be the same because the river flows uniformly like a heated brick moving from one place to the other.

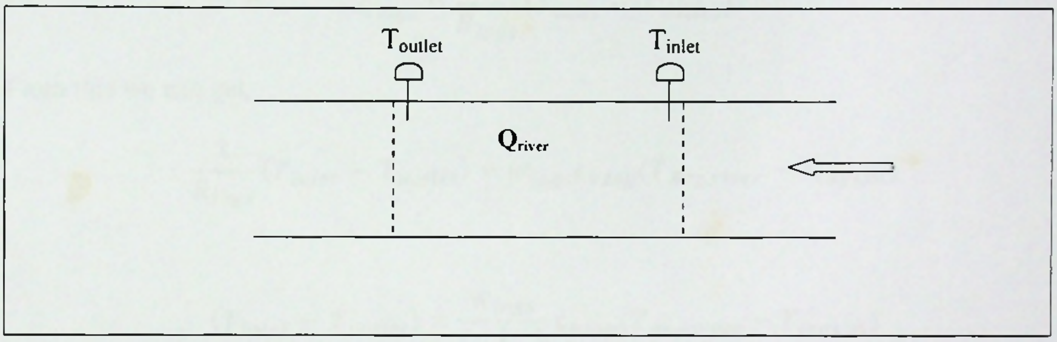


Figure 2.1 Fully insulated river with no heat loss and continuous flow.

If no heat loss

$$T_{outlet} = T_{inlet} \quad \text{and the Heat of the river } Q_{river} \text{ is constant}$$

Let us consider an event of dropping wood logs into the river at portion of our interest. The logs will float in the direction of the flow of the river absorbing the heat from the river water. Suppose that the flow of dropping of logs into the river is continuously happening. Then.

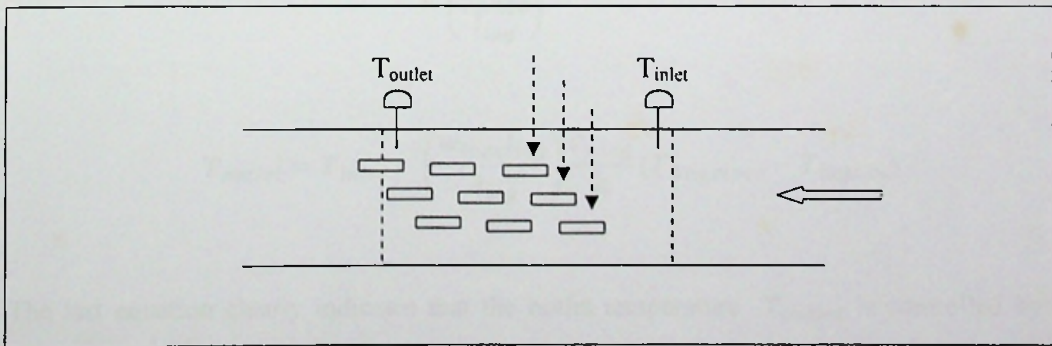


Figure 2.2 River is subjected to a continuous flow of logs into to it.

2.3 Heat Model of the River

According to equation 2.4 the heat flowed into the logs (q_{logs}) as a result of falling of logs into the river (w_{logs} = mass flow rate of logs into the river, $c_{v,log}$ = specific heat of logs);

$$q_{logs} = w_{logs} c_{v,log} (T_{Avg,river} - T_{logs,in})$$

If this is the only heat loss happens in the river let us consider the heat transferred to fiber as a result of thermal resistance which is the same amount transferred due to flow. The temperature difference of the RTDs comes as a result of this transfer of heat. Using the equation 2.1 we can write (R_{logs} = Thermal resistance of logs);

$$q_{logs} = \frac{1}{R_{logs}} (T_{inlet} - T_{outlet})$$

From this we can get,

$$\frac{1}{R_{logs}} (T_{inlet} - T_{outlet}) = w_{logs} c_{v,log} (T_{Avg,river} - T_{logs,in})$$

$$(T_{inlet} - T_{outlet}) = \frac{w_{logs}}{\left(\frac{1}{R_{logs}}\right)} c_{v,log} (T_{Avg,river} - T_{logs,in})$$

$$T_{outlet} = T_{inlet} - \frac{w_{logs}}{\left(\frac{1}{R_{logs}}\right)} c_{v,log} (T_{Avg,river} - T_{logs,in})$$

$$T_{outlet} = T_{inlet} - \frac{w_{logs}}{\left(\frac{kA_{log}}{l_{log}}\right)} c_{v,log} \left(T_{Avg,river} - T_{logs,in}\right)$$

$$T_{outlet} = T_{inlet} - \left(\frac{w_{logs} l_{log}}{A_{log}}\right) \frac{c_{v,log}}{k} (T_{Avg,river} - T_{logs,in})$$

The last equation clearly indicates that the outlet temperature T_{outlet} is controlled by the factor $\left(\frac{w_{logs} l_{log}}{A_{log}}\right)$ while all the other variables become constant or to a negligible state. Here to increase the outlet temperature one has to reduce this factor. To reduce the factor he has to reduce the flow and increase the area of logs.

2.4 The Dryer

The same analogy applies in the case of the dryer. We will consider the losses and other quantities which were not considered in the river model. But we can see most will cancel and the remaining quantities would be almost the same as in the river model.

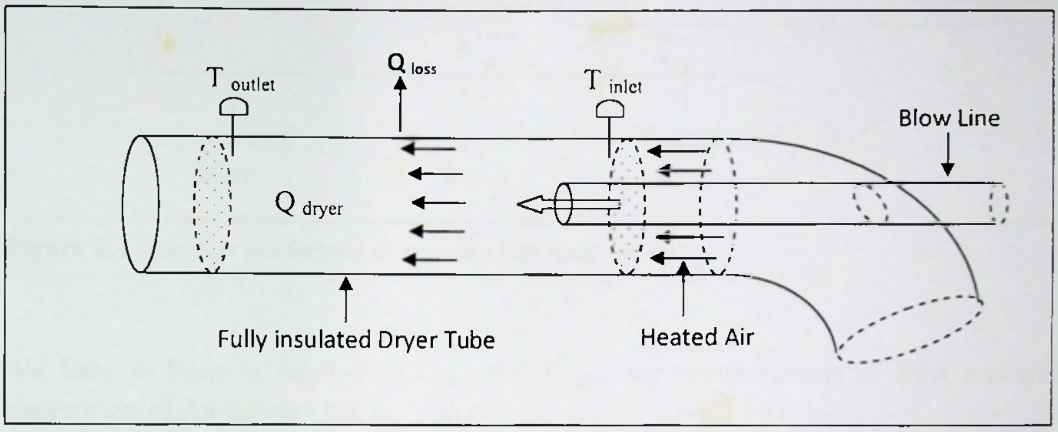


Figure 2.3 Fully insulated dryer with constant air flow and hence continuous heat flow but no flow of fiber into it.

2.5 Heat Model of the Dryer

In figure 2.3 it shows the dryer with no fiber flow but has continuous air flow and constant heat since not heat loss can be happen due to complete insulation.

The fiber is bring in through the blow line same as in the river released inside the area of our interest and the continuous flow of air with constant supply of heat comes away from the portion of consideration which is also the same as in case of river.

Let us assume that the Air has a continuous heat loss along the tube which is Q_{loss}.

If the temperature of the exchanger is T_{EX}, then the heat transferred to Air (q_{air}) from the heat exchanger, according to equation 2.1;

$$q_{air} = \frac{1}{R_{EX}}(T_{EX} - T_{inlet})$$

R_{EX} = Thermal Resistance of heat exchanger. T_{inlet} = Inlet Air temperature.

If heat loss is Q_{loss} then the heat transferred to Air,

$$Q_{air} = q_{air} - Q_{loss}$$

$$Q_{air} = \frac{1}{R_{EX}}(T_{EX} - T_{inlet}) - Q_{loss}$$

Now consider the situation of flowing of fiber into the dryer,

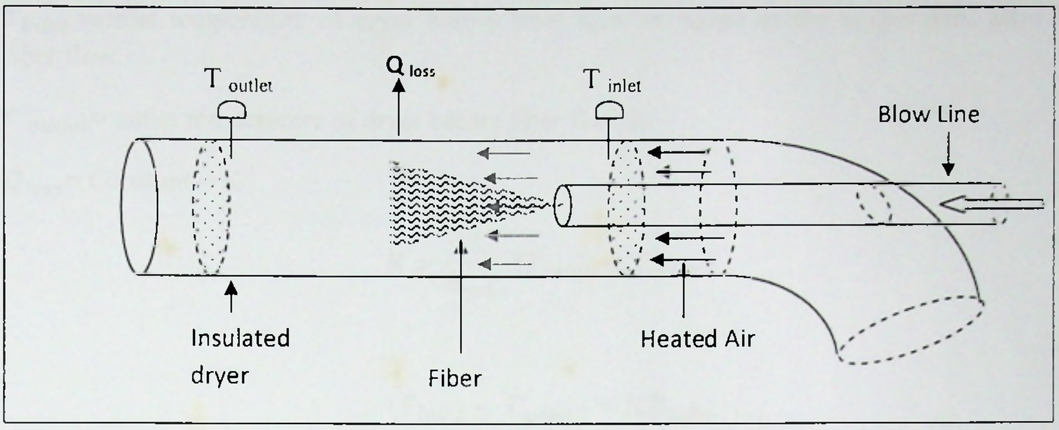


Figure 2.4 Fiber flow into the river of Air with a high mass flow rate.

We have to keep in mind that T_{inlet} and T_{oulet} are measurements of inlet and outlet temperature of Air flowing inside the dryer.

The amount of heat transferred to fiber as a result of flowing into the hot Air stream,

$$q_{fiber} = w_{fiber} c_{v,fiber} (T_{Avg,air} - T_{fiber,in})$$

The net heat remaining in the Air after flowing of fiber into it is,

$$Q_{air} = \frac{1}{R_{EX}} (T_{EX} - T_{inlet}) - q_{fiber} - Q_{loss}$$

$$Q_{air,net} = \frac{1}{R_{EX}} (T_{EX} - T_{inlet}) - w_{fiber} c_{v,fiber} (T_{Avg,air} - T_{fiber,in}) - Q_{loss} \quad 2.5$$

Now let us consider on the other way around. If there is not heat loss then the inlet and outlet temperatures of the dryer has to equal. But there is a constant heat loss. So there should be a temperature difference. But the difference is constant because the loss is constant. Due to this reason again we can consider that there is no change happens in the inlet or outlet temperatures of dryer until the fiber is flowed in to it. It can be shown as follows.

$$Q_{loss} = \frac{1}{R_{tube}} (T_{inlet} - T'_{oulet})$$

Here,

T_{inlet} = Inlet temperature of dryer before fiber flow in. Same as the temperature after the fiber flow.

T'_{outlet}= outlet temperature of dryer before fiber flow in.

Q_{loss}= Constant = K

$$K = \frac{1}{R_{tube}}(T_{inlet} - T'_{oulet})$$

$$(T_{inlet} - T'_{oulet}) = KR_{tube}$$

$R_{tube} = \frac{kA_{tube}}{l_{tube}}$ = Constant, because the dimensions are constant in the dryer.

$$(T_{inlet} - T'_{oulet}) = contant$$

After the fiber starts flowing in the outlet temperature will be reduced due to the heat flow into the fiber as a transfer.

$$T'_{oulet} - \Delta T = final\ outlet\ temperature$$

$$\Delta T = T'_{oulet} - T_{oulet}$$

$$T'_{oulet} - (T'_{oulet} - T_{oulet}) = final\ outlet\ temperature$$

$$T_{oulet} = final\ outlet\ temperature$$

$$T_{oulet} = T'_{oulet} - \Delta T$$

$$T_{oulet} = T_{inlet} - contant - \Delta T$$

$$T_{oulet} = T_{inlet} - \Delta T' \qquad ; \Delta T' = contant + \Delta T$$

So the reduction of heat in the Air in addition to the reduction of heat due to the loss is equal to the transfer of heat to the fibers from Air. This reduction of heat from Air gives rise to the new outlet temperature, T_{oulet}.

Let us assume each and every fiber is equal dimensions after grinding in the refiner. Actually they are almost equal size. The difference can be measured by using vibrating meshes. The vibrator has different meshes for different sizes. We put the fiber sample on the top most mesh which has the largest holes. The lowest one has the smallest holes. After vibrating a known period of time we measure the fiber collected in each tray separately. So percentage of fiber collected in each tray can be obtained and if more than 80% of fiber collected in the required size the sample can be considered as suitable for the production. The size normally using is approximately, 2 -3mm in length and 0.25- 0.7mm in thickness.

Let us consider the heat absorb by one fiber from Air,

$$q_i = \frac{1}{R_i}(T_{inlet} - T_{outlet})$$

The heat absorbed by n number of fibers,

$$q_{fiber} = \sum_{i}^{n} q_i = \sum_{i}^{n} \left[\frac{1}{R_i}(T_{inlet} - T_{outlet})\right]$$

$$q_{fiber} = (T_{inlet} - T_{outlet}) \sum_{i}^{n} \left[\frac{kA'_i}{l_i}\right]$$

$$q_{fiber} = (T_{inlet} - T_{outlet}) k \sum_{i}^{n} \left(\frac{A'}{l}\right)_i$$

$$q_{fiber} = (T_{inlet} - T_{outlet}) kn \left(\frac{A'}{l}\right)$$

$$q_{fiber} = \frac{k(nA')}{l}(T_{inlet} - T_{outlet})$$

Take $[nA' = A_{fiber}]$ the total area of fibers inside the dryer and assume lengths of fibers are approximately equal.

$$q_{fiber} = \frac{kA_{fiber}}{l_{fiber}}(T_{inlet} - T_{outlet})$$

$$\frac{1}{R_{fiber}} = \frac{kA_{fiber}}{l_{fiber}}$$

So the equation again becomes,

$$q_{fiber} = \frac{1}{R_{fiber}}(T_{inlet} - T_{outlet})$$

So the net heat of Air after derived on the other way around using inlet and outlet temperature,

$$Q_{air,net} = \frac{1}{R_{EX}}(T_{EX} - T_{inlet}) - \frac{1}{R_{fiber}}(T_{inlet} - T_{outlet}) - Q_{loss} \qquad 2.6$$

2.6 The Key

From the equations 2.5 and 2.6 we get,

$$\frac{1}{R_{EX}}(T_{EX} - T_{inlet}) - \frac{1}{R_{fiber}}(T_{inlet} - T_{outlet}) - Q_{loss}$$

$$= \frac{1}{R_{EX}}(T_{EX} - T_{inlet}) - w_{fiber}c_{v,fiber}(T_{Avg,air} - T_{fiber,in}) - Q_{loss}$$

Simplifying the equation,

$$\frac{1}{R_{fiber}}(T_{inlet} - T_{outlet}) = w_{fiber}c_{v,fiber}(T_{Avg,air} - T_{fiber,in})$$

$$(T_{inlet} - T_{outlet}) = \frac{w_{fiber}}{\left(\frac{1}{R_{fiber}}\right)}c_{v,fiber}(T_{Avg,air} - T_{fiber,in})$$

$$T_{outlet} = T_{inlet} - \frac{w_{fiber}}{\left(\frac{1}{R_{fiber}}\right)}c_{v,fiber}(T_{Avg,air} - T_{fiber,in})$$

$$T_{outlet} = T_{inlet} - \frac{w_{fiber}}{\left(\frac{kA_{fiber}}{l_{fiber}}\right)}c_{v,fiber}(T_{Avg,air} - T_{fiber,in})$$

$$T_{outlet} = T_{inlet} - \left(\frac{w_{fiber}l_{fiber}}{A_{fiber}}\right)\frac{c_{v,fiber}}{k}(T_{Avg,air} - T_{fiber,in}) \qquad 2.7$$

The equation 2.7 is the **key** of our control design. The control of outlet temperature will control the moisture level of fiber under a known relationship of moisture and outlet temperature.

The next chapter will explain how this equation plays his role in the design of our control system of moisture control. This equation is basically used to understand what really is done by the operators in the manual process of controlling moisture.

Chapter 3

The Controller

The design of a fully automatic controller contains two basic steps.

1. Design of a cascaded PID system for the control of moisture until the steam PRV is 100% open.
2. Coupling of the multistage control algorithm with the cascaded PID for the control of moisture after the steam PRV is 100% open.

3.1 The Cascaded PID

The control system before this modification contained a PID for the outlet temperature. The operator has to monitor the moisture content continuously in the HMI (Human Machine Interface) and has to put the appropriate temperature set point to meet the required moisture content. The moisture content is a requirement depends on the thickness of the board and has to be changed sometimes during the same thickness.

The set-point of the outlet temperature PID decides the position of the steam PRV and asks the PLC to output the analog control signal to the actuator of the steam PRV.

The amount of steam come into the heat exchange via this valve determine how much heat that can be supplied to the air passing through it and hence how much temperature can rise in the air.

The basic failure undergoes in the prevailing system is when the operators are unaware of the moisture content of fiber in some unavoidable situations it can go very high and the occurrence of basic human errors.

To eliminate this, a cascaded PID system can be developed to monitor the moisture content continuously replacing the operator's eye and the set-point which is set at the moisture PID will determine the temperature set-point of the outlet temperature PID and this temperature set point decides the valve position or the control variable of the steam PRV.

The operator has to decide the set point of moisture he requires and can forget about it until the PRV get 100% open. The PRV would never get 100% open if the weather condition is good enough to give dry and warm air into the dryer. So in dry weather this PID system will control moisture without any interference of refiner operators.

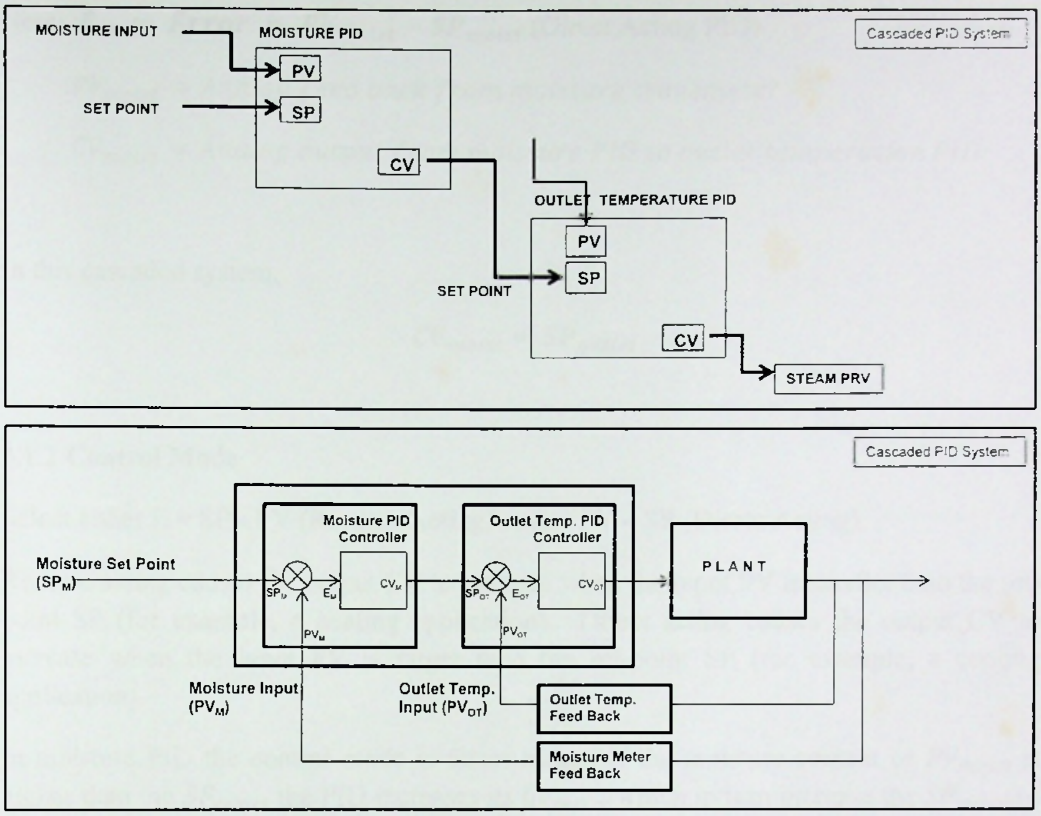


Figure 3.1 The proposed cascaded PID system

3.1.1 The PID equation

The PID equation controls the process by sending an output signal to the control valve. The greater the error between the set-point and process variable input, the greater the output signal, and vice versa. An additional value (feed forward or bias) can be added to the control output as an offset. The result of the PID calculation (control variable) will drive the process variable towards the set point. The PID equation used in RSLogix500 (The programming software) according to the manuals is,

$$CV = k_C\left[(E) + \frac{1}{T_i}\int(E)dt + T_d\frac{d(PV)}{dt}\right] + bias$$

So the CV of moisture PID,

$$CV_{moist} = k_{C_M}\left[(E_M) + \frac{1}{T_{i_M}}\int(E_M)dt + T_{d_M}\frac{d(PV_{moist})}{dt}\right]$$

Here: $\boldsymbol{E_M} = \boldsymbol{Error} = \boldsymbol{PV_{moist}} - \boldsymbol{SP_{moist}}$ (Direct Acting PID)

$PV_{moist} = Analog\ feed\ back\ from\ moisture\ transmeter$

$CV_{moist} = Analog\ output\ from\ moisture\ PID\ to\ outlet\ temperation\ PID$

In this cascaded system,

$$\boldsymbol{CV_{moist} = SP_{outlet}}$$

3.1.2 Control Mode

Select either E = SP - PV (Reverse Acting) or E = PV – SP (Direct Acting).

Reverse acting causes the output CV to increase when the input PV is smaller than the set-point SP (for example, a heating application). Direct acting causes the output CV to increase when the input PV is larger than the set-point SP (for example, a cooling application).

In moisture PID the control mode is direct acting. If the moisture content or PV_{moist} is higher than the SP_{moist} the PID increases its CV_{moist} which in turn increase the $SP_{outlet}$of the outlet temperature PID, because in this cascade system $CV_{moist} = SP_{outlet}$.

The outlet-temperature PID gets the outlet-temperature RTD feedback and calculates the Error for his calculations. The control mode is reverse acting.

$$\boldsymbol{E_{OT} = SP_{outlet} - PV_{outlet}}$$

From the cascade relationship,

$$\boldsymbol{E_{OT} = CV_{moist} - PV_{outlet}}$$

so in the equation of the outlet PID we can see,

$$\boldsymbol{CV_{outlet}} = k_{C_{OT}}\Bigg[(\boldsymbol{CV_{moist} - PV_{outlet}}) + \frac{1}{T_{i_{OT}}}\int(\boldsymbol{CV_{moist} - PV_{outlet}})dt + T_{d_{OT}}\frac{d(\boldsymbol{CV_{moist} - E_{OT}})}{dt}\Bigg]$$

Here,

$$\boldsymbol{CV_{moist}} = k_{C_M}\left[(E_M) + \frac{1}{T_{i_M}}\int(E_M)dt + T_{d_M}\frac{d(PV_{moist})}{dt}\right]$$

These equations easily show the interrelationship of variables of moisture and variables of outlet temperature. The equation shows why the moisture set point defines the steam PRV position.

3.1.3 Tuning the PID Gains

The gains of the PIDs can be tuned using the software provided instructions and other control theories on PID control.

Controller Gain (k_{C_M} & $k_{C_{OT}}$)

This is the proportional gain. Generally set this gain to one half the value needed to cause the output to oscillate when the reset and rate terms are set to zero.

Reset Term (T_{i_M} & $T_{i_{OT}}$)

Type in a value representing minutes. This is the integral gain. Generally set the reset time equal to the natural period measured in the Gain calibration above

Rate Term (T_{d_M} & $T_{d_{OT}}$)

Type in a value representing minutes. This is the derivative term. Generally set this value to 1/8 of the integral time above.

This tuning criterion is provided by the programming software of the PLC used in the design of the control system. It doesn't matter which criteria is used, the important matter is whether it can control the process.

3.2 The Multistage Controller

Now we come to the problem of outlet temperature control after the steam PRV is 100% open. This T_{Outlet} or in other words the outlet temperature controls the Moisture content of fiber. Increasing T_{Outlet} will decrease the Moisture content and decreasing T_{Outlet} will increase the Moisture content.

When the PRV is 100% open whatever the system can do with steam on controlling the outlet temperature comes to a limit.

Since steam is the only source of energy that can be applied to the system, this limit gives the margin of energy injection to the system in increasing the outlet temperature.

The Key Equation 2.7 shows that the outlet temperature can be still controllable even after the steam PRV is 100% open where no more controllability can be achieved with it.

Let us see what happens to the dryer when the PRV is at 100% open position using the Key Equation 2.7.

$$T_{outlet} = T_{inlet} - \left(\frac{w_{fiber} l_{fiber}}{A_{fiber}}\right) \frac{c_{v,fiber}}{k} (T_{Avg,air} - T_{fiber,in})$$

At this condition, maximum energy is transferred to the Air from the exchanger and due to this T_{inlet} rises to its maximum value which becomes a constant at the end.

Let us take,

$$T_{inlet} = K_1 = Constant1$$

The fiber travel though the blow line released inside the dryer closer to the inlet temperature RTD when comparable to the length of the dryer. So an assumption can be made on the temperature region from which the fibers get heated.

$T_{Avg,air}$ is the temperature of the region to where the fiber is released in the dryer. Since this area is closer to the inlet temperature and the inlet temperature is at its maximum level let $T_{Avg,air}$ be equal to T_{inlet} which is a constant, K_1.

$T_{fiber,in}$ is also approximately constant because the temperature changes in fiber during their travel in blow line is hardly noticeable and almost the same at every time. The process from refiner to blow line is always going with fix parameters in temperature wise. Let's take $T_{fiber,in} = K_2$.

So the equation 2.7 then becomes,

$$T_{outlet} = K_1 - \left(\frac{w_{fiber} l_{fiber}}{A_{fiber}}\right) \frac{c_{v,fiber}}{k} (K_1 - K_2)$$

$$T_{outlet} = K_1 - \left(\frac{w_{fiber} l_{fiber}}{A_{fiber}}\right) K_3 \qquad ; K_3 = \frac{c_{v,fiber}}{k} (K_1 - K_2)$$

$$T_{outlet} = K_1 \left[1 - K_4 \left(\frac{w_{fiber} l_{fiber}}{A_{fiber}}\right)\right] \qquad ; K_4 = \frac{K_3}{K_1}$$

$$T_{outlet}^{100\%} = K_1\left\{1 - K_4\left[w_{fiber}\left(\frac{l_{fiber}}{A_{fiber}}\right)\right]\right\} \qquad 3.1$$

This clearly indicates that $T_{outlet}^{100\%}$ is a function of the expression $\left[w_{fiber}\left(\frac{l_{fiber}}{A_{fiber}}\right)\right]$.

So, according to the equation it can be easily shown that by ***decreasing*** the factor $\left(\frac{l_{fiber}}{A_{fiber}}\right)$ and by ***decreasing*** the amount w_{fiber} the outlet temperature T_{outlet} can be ***increased.***

Decreasing the factor $\left(\frac{l_{fiber}}{A_{fiber}}\right)$ means decreasing l_{fiber} and increasing A_{fiber}.

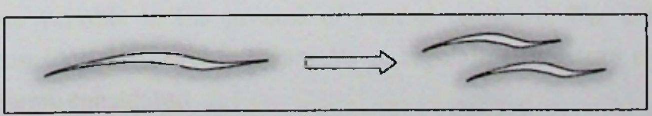
3.2.1 The Blow Valve

Let us consider the first control parameter $\left(\frac{l_{fiber}}{A_{fiber}}\right)$.

The value of $\left(\frac{l_{fiber}}{A_{fiber}}\right)$ can be decreased by increasing the area and reducing the length of fiber. The way of doing this can be described as follows.

The situation is practically achieved by closing or opening the Refiner Blow Valve. The amount of closing or in other words the percentage value of Valve Position reasonably determines the factor $\left(\frac{l_{fiber}}{A_{fiber}}\right)$.

When the Blow Valve position is reduced by a known amount the fiber output is damped making the fiber stay some additional time inside the Disk Chamber where it may grinds further. As a result of this a normal fiber can split into two or more fibers increasing the total area and the total length of a fiber. It was noticed by long term practice this reduction of blow valve by small amount does not matter in the reduction of the fiber output. This is because the closing of blow valve creates more pressure inside the Disk Chamber developing more outward tendency in fiber. This outward tendency compensates the restriction creates by the Blow Valve.



It will be shown later how this Percent value of Blow Valve position or simply the Blow Valve Position (B_{Valve}) work as a basic parameter in controlling moisture content of fiber. The relationship can be realized as follows;

$$B_{Valve} \propto \frac{l_{fiber}}{A_{fiber}}$$

This indicates that $\frac{l_{fiber}}{A_{fiber}}$ is a function of Blow Valve. This can be written as follows;

$$\frac{l_{fiber}}{A_{fiber}} = f_1(B_{Valve}) \qquad 3.2$$

Note;

When the area of fiber (A_{Fiber}) is increased not only absorption of heat can become high but also the emission. So, this emission again will affect in the increment of heat inside the dryer where it can be again absorbed by Air or fiber depending on their temperature levels.

3.2.2 The Feed Screw Speed

Then consider the other parameter w_{fiber}. This flow rate depends on two variables of the refiner. One is feed screw RPM and the other one is differential pressure. But 80% of the control is on feed screw RPM where as the rest belongs to the other one, the differential pressure.

Suppose the relationship of flow rate to the feed screw speed can be written as the following function,

$$w_{fiber} = G(RPM_{FS}) \qquad 3.3$$

3.2.3 The Differential Pressure

Then consider the relationship of flow rate to differential pressure,

In addition to these two parameters, that is Blow Valve and Feed Screw Speed the operators regulate one more variable in the process of control moisture. The Differential Pressure (P_{diff}) is also considered as a basic parameter in regulating moisture content after all the other parameters were considered.

In the refiner, the differential pressure is the pressure difference between the top pressure and the bottom pressure.

$$P_{diff} = P_{top} - P_{bottom}$$

More clearly speaking there is no such physical valve called differential pressure valve but a pseudo valve which has been simulated to control the bottom pressure valve. The refiner pressure system has two pressure regulating valves (PRV's) for bottom pressure and top pressure. Two PID controllers work together for the control of this pressure system.

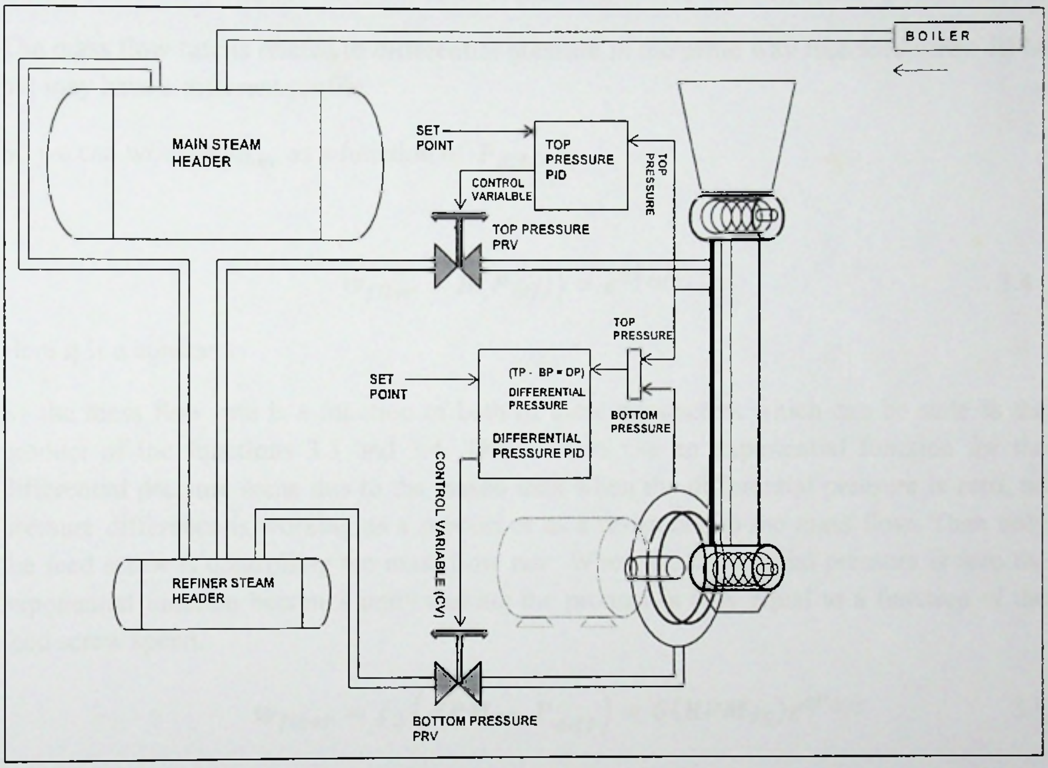


Figure 3.2 The differential pressure PID. The pseudo valve for the controlling the bottom pressure PRV.

Here, bottom pressure PRV is controlled by the differential pressure PID and the top pressure is controlled by the top pressure PID. Figure 3.2 shows schematically how the differential pressure works in the refiner.

If the operator puts a positive set point, then the bottom pressure should be less than the top pressure and if he puts a negative set point then the bottom pressure becomes higher than the top pressure. This negative condition damps the downward flow of mass and creates a condition which has an upward tendency. Although the mass never go upward under this condition the downward flow reduces.

So, this will result in a reduction of fiber flow rate or in other word a reduction in the fiber production in the refiner. This reduction of mass flow rate directly affects in an increment in the outlet temperature and is theoretically explained in the relationship constructed above.

This reduction of outlet temperature at the dryer affects in the reduction of the moisture content of fiber in the process. Here, same as in the case of feed screw speed (RPM_{FS}), the differential pressure (P_{diff}), also controls the mass flow rate of fiber (w_{Fibr}).

The same mass flow rate is controlled by the differential pressure and the affect of this control parameter is lighter than the affect of the former one, the feed screw speed.

The mass flow rate is related to differential pressure in the same way like feed screw RPM but may have a different profile.

So we can write, w_{fiber} as a function of P_{diff}.

$$w_{fiber} = H(P_{diff}) = e^{\eta P_{diff}} \qquad 3.4$$

Here η is a constant.

So the mass flow rate is a function of both of these parameters which can be state as the product of the functions 3.3 and 3.4. The need to use an exponential function for the differential pressure came due to the reason than when the differential pressure is zero, no pressure difference is working as a support or as a resistance to the mass flow. Then only the feed screw is controlling the mass flow rate. When the differential pressure is zero the exponential function becomes unity making the product is only equal to a function of the feed screw speed.

$$w_{fiber} = f_2\left(RPM_{FS}, P_{diff}\right) = G(RPM_{FS})e^{\eta P_{diff}} \qquad 3.5$$

Then considering the equation 3.1 again we get,

$$T_{outlet}^{100\%} = K_1\left\{1 - K_4\left[f_2\left(RPM_{FS}, P_{diff}\right) \times f_1(B_{Valve})\right]\right\} \qquad 3.6$$

Expanding the equation 3.6 we get,

$$T_{outlet}^{100\%} = K_1\{1 - K_4[G(RPM_{FS}) \times e^{\eta P_{diff}} \times f_1(B_{Valve})]\} \qquad 3.7$$

So the equation that governs the multistage controller will be equation 3.7, where the three functions of variables, blow valve, feed screw speed and differential pressure are well constituted.

After this by taking one parameter as the independent variable at a time, making the remaining two constants, the relationship of this particular variable with the outlet temperature has to be derived.

Like this three functions can be derived for the outlet temperature taking one at a time as a variable. These can be showed as follows.

Taking blow valve, B_{Valve} , as the independent variable we get the outlet temperature as a function of the blow valve position under the condition of steam PRV 100% open,

$$T_{outlet}^{100\%} = K_1\{1 - K_5 f_1(B_{Valve})\} \qquad 3.8$$

Where $K_5 = K_4 \times \left[G(RPM_{FS}) \times e^{\eta P_{diff}}\right]_{const}$ is a constant.

Then taking feed screw speed, RPM_{FS} , as the independent variable we get the outlet temperature as a function of the feed screw speed under the condition of steam PRV 100% open.

$$T_{outlet}^{100\%} = K_1\{1 - K_6 G(RPM_{FS})\} \qquad 3.9$$

Where $K_6 = K_4 \times \left[e^{\eta P_{diff}} \times f_1(B_{Valve})\right]_{const}$ is a constant.

Then taking the differential pressure, P_{diff} , as the independent variable we get the outlet temperature as a function of the differential pressure set point under the condition of steam PRV 100% open.

$$T_{outlet}^{100\%} = K_1\{1 - K_7 e^{\eta P_{diff}}\} \qquad 3.10$$

Where $K_7 = K_4 \times \left[G(RPM_{FS}) \times f_1(B_{Valve})\right]_{const}$ is a constant.

After obtaining the theoretical relationships of each variable with outlet temperature the experimental data were collected separately for each variable (taking one as the independent variable while the others are constant).

3.2.4 Experimental Data

The experimental data cannot be collected for the full range of any variable. As an example we cannot fully close the blow valve while the refiner is running. Because the fully close of blow valve will fully cut the mass flow. This will increase the grinding house pressure creating a very high current which will cause the main motor to trip. (The safety relays are set in Merbok in order to prevent the 2.2MW motor from drawing high current. This is common to every industry involving high capacity motors.)

In the same way, we cannot fully stop the feed screw which will stop the production entirely. Stopping the feed screw doesn't harmful to any machinery because stopping it would automatically stop the column feeding screw after the level goes higher than the column-height set point.

The differential pressure is also varied in between a range which is not harmful to the system. The negative increment of differential pressure will increase the bottom pressure higher than the top pressure which will result in a negative tendency in the flow. Although it never flows in the negative direction the output will get reduced. When the differential pressure is increased negatively beyond the operational range it causes in several other problems. They may be either an increment in main motor current as a result of the high grinding house pressure or a fluctuation in the top pressure.

After the formulation of the theoretical model (equation 3.7) and then after getting an isolated model for each variable by making the others constant, it was well understood that the outlet temperature will get a definite relationship independently with each variable.

After each step change of any variable the effect is felt by the outlet temperature, but it takes around 2 minutes to settle in a particular temperature level. This two minutes time interval is common to all three variables and data was recorded after every 2 minutes under each independent variable.

The equations of the functions can be derived using the experimental data taken by maintaining the conditions set in the development of the theoretical functions.

3.2.5 The experimental data plot obtained for the blow valve position.

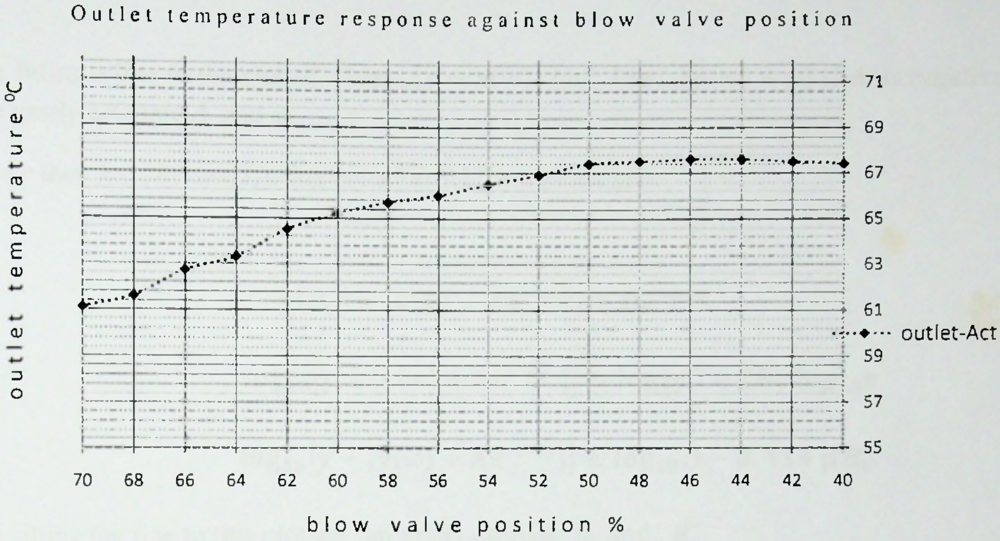


Figure 3.3 The outlet temperature plot against blow valve position.

To obtain a model from this response let us assume that the response is given by a sum of exponentials.

$$y(B_{Valve}) = y(\infty) + Ae^{-\alpha B_{Valve}} + De^{-\beta B_{Valve}} + Fe^{-\gamma B_{Valve}} + \cdots \qquad 3.11$$

Here $y(\infty)$ will be the maximum value that $T_{outlet}^{100\%}$ can get when blow valve is in its minimum position. (But keep in mind that we cannot close the blow valve to zero position. The minimum can be 30 %.)

Subtracting off the final value and assuming that $-\alpha$ is the slowest pole, it can written,

Taking $B_{Valve} = B_V$

$$\mathbf{y - y(\infty) \cong Ae^{-\alpha B_V}}$$

$$\mathbf{\log_{10}[y - y(\infty)] \cong \log_{10}\left(\frac{A}{e^{\alpha B_V}}\right)}$$

$$\mathbf{\log_{10}[y - y(\infty)] \cong \log_{10}A - \alpha B_V \log_{10}e}$$

$$\log_{10}[y - y(\infty)] \cong \log_{10}A - 0.434\,\alpha\,B_V \qquad 3.12$$

This is the equation of line whose slope would determine α and intercept would determine A.

By fitting a line to the plot of $\log_{10}[y - y(\infty)]$ (or $\log_{10}[y(\infty) - y]$ if A is negative), we easily estimate A and α.

Once they are estimated, using equation 3.11, we plot again;

$$y(B_V) - [y(\infty) + Ae^{-\alpha B_V}] \cong De^{-\beta B_V} \qquad 3.13$$

$$\log_{10}[y - [y(\infty) + Ae^{-\alpha B_V}]] \cong \log_{10}D - \beta B_V \log_{10}e$$

$$\log_{10}[y - [y(\infty) + Ae^{-\alpha B_V}]] \cong \log_{10}D - 0.434\,\beta\,B_V$$

By fitting the line to this plot we can easily estimate D and β.

The process can be repeated removing the slowest remaining term until the data stop being accurate. So if we repeat,

$$\log_{10}\left[y - \left[y(\infty) + Ae^{-\alpha B_V} + Be^{-\beta B_V}\right]\right] \cong \log_{10}F - 0.434\,\gamma\,B_V$$

Taking $y(B_V) = T_{outlet}^{100\%} = T_{out,\,B_V}^{100\%}$

$y(\infty) = T_{out,\,B_{V,max}}^{100\%}$

$$\log_{10}\left[T_{out,\,B_V}^{100\%} - \left[T_{out,\,B_{V,max}}^{100\%} + Ae^{-\alpha B_V} + Be^{-\beta B_V}\right]\right] \cong \log_{10}F - 0.434\,\gamma\,B_V$$

By fitting a line for the log plot F and γ can be estimated.

We can continue this until the best fit is found for the experimental data plot. Once the best fit is found it can be used to formulate the transfer function that may control the process or the system of our interest.

Now let us consider the data plot of figure 3.3 for obtaining the experimental function. Consider the equation,

$$\log_{10}[y - y(\infty)] \cong \log_{10}A - 0.434\ \alpha\ B_V$$

$$\log_{10}[y(\infty) - y] \cong \log_{10}A - 0.434\ \alpha\ B_V \qquad : \text{A is negative}$$

Let us take $y(\infty) = T^{100\%}_{out,\ B_{V,max}} = 68$

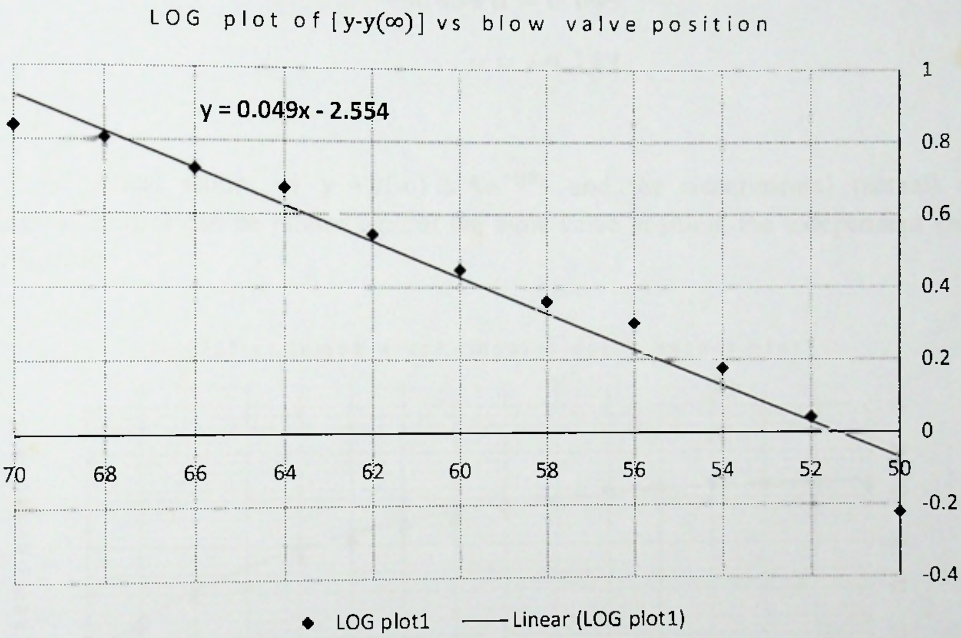


Figure 3.4 The plot of $\log_{10}[y(\infty) - y]$ against B_V

By looking at the figure 3.3 let us consider that $y(\infty) \cong 68$ and A is negative since $y(\infty)$ is greater than $y(B_V)$. Using the data of figure 3.3 we can plot the graph of $\log_{10}[y(\infty) - y]$. The figure 3.4 shows the data plot of $\log_{10}[y(\infty) - y]$ and from the line fitted to the plot we can determine A and α of the following equation.

$$\log_{10}\left[T^{100\%}_{out,\ B_{V,max}} - T^{100\%}_{out,\ B_V}\right] \cong \log_{10}A - 0.434\ \alpha t$$

The equation of the trend line is;

$$Y_{trend} = 0.049x - 2.554$$

At $y = 0,\ x = 52.122$

By the comparison of two equations we get,

$$\log_{10}|A| = -2.554$$

$$A = -0.0028\ ; \qquad A \text{ is negative.}$$

$$-0.434\,\alpha = 0.049$$

$$\alpha = -0.113$$

The theoretical values of $\mathbf{y - y(\infty) \cong Ae^{-\alpha B_v}}$ and the experimental (actual) outlet temperature data can be plotted against the blow valve position, the independent variable considered.

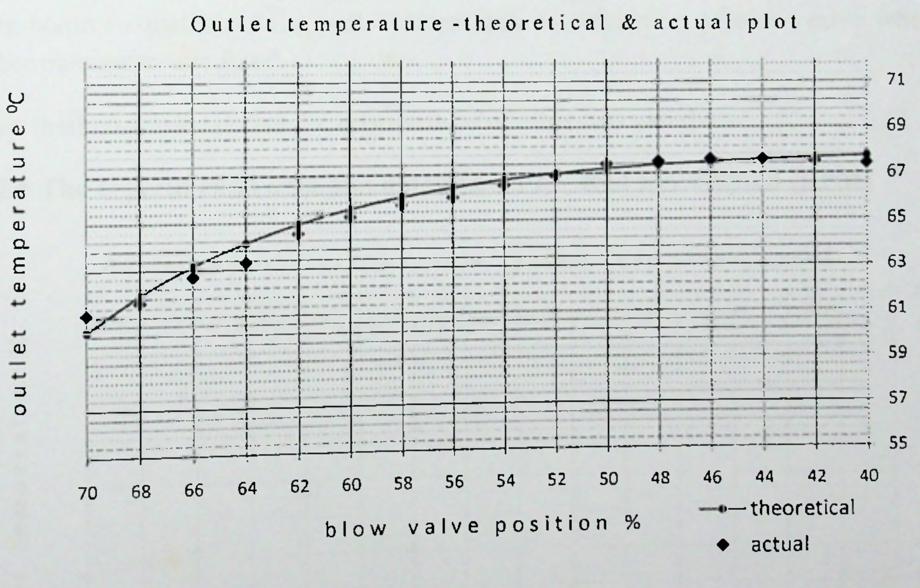


Figure 3.5 Theoretical and experimental plot of outlet temperature against blow valve position

The theoretical plot matches reasonable good with the experimental data plot and therefore we can state the theoretical relationship of outlet temperature to blow valve position when taking all the other variables including steam PRV is constant.

From equation 3.11

$$y(B_{Valve}) = y(\infty) + Ae^{-\alpha B_{Valve}} + De^{-\beta B_{Valve}} + Fe^{-\gamma B_{Valve}} + \cdots$$

The best fit is found at the pole - α and then the equation is,

$$y(B_{Valve}) = y(\infty) + Ae^{-\alpha B_{Valve}}$$

Substituting the values obtained from the experimental plot,

$$T_{outlet}^{100\%}\Big|_{B_{Valve}} = 68 - 0.0028\, e^{+0.113(B_{Valve})} \qquad 3.14$$

The control equation of the outlet temperature is a function of blow valve when all the other parameters are fixed.

This method is used derive the relationships of other two variables.

3.2.6 The experimental data plot obtained for the feed screw speed (RPM)

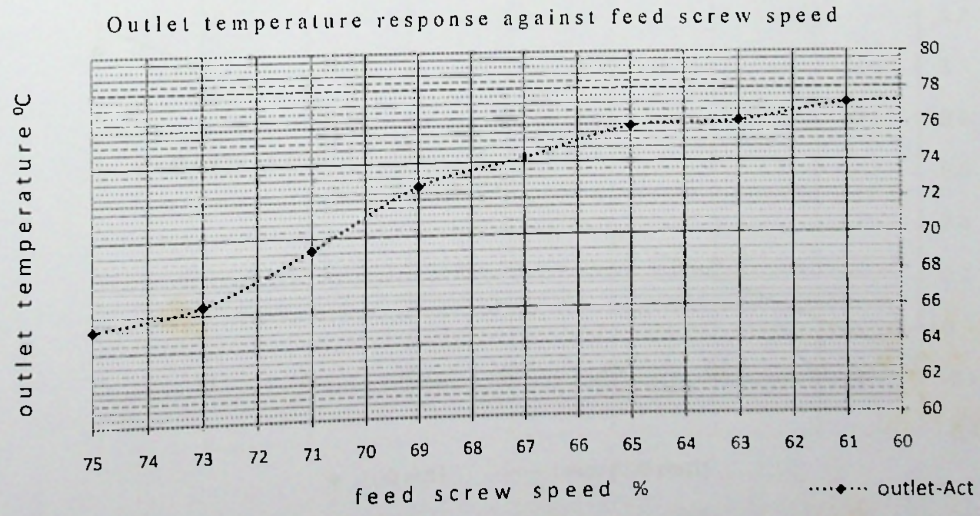


Figure 3.6 The outlet temperature plot against feed screw speed(RPM_{FS}).

Assume that the response is given by a sum of exponentials as in the case of the blow valve,

$$y(RPM_{FS}) = y(\infty) + Ae^{-\alpha\, RPM_{FS}} + De^{-\beta\, RPM_{FS}} + Fe^{-\gamma\, RPM_{FS}} + \cdots \qquad 3.15$$

Here $y(\infty)$ will be the maximum value that $T_{outlet}^{100\%}$ can get when feed screw speed is in the lowest speed in the situation considered. (But keep in mind that we cannot slow down the feed speed to zero. If this is zero, the production will stop. The minimum can be 20 %.)

Subtracting off the final value of the equation 3.15 and assuming that $-\alpha$ is the slowest pole, it can be written,

$$y - y(\infty) \cong Ae^{-\alpha(RPM_{FS})}$$

By looking at the figure 3.6 let us consider that $y(\infty) \cong 78$ and A is negative since $y(\infty)$ is greater than $y(RPM_{FS})$. Using the data of figure 3.6 we can plot the graph of $\log_{10}[y(\infty) - y]$. The figure 3.7 shows the data plot of $\log_{10}[y(\infty) - y]$ and from the line fitted to the plot we can determine A and α of the following equation

$$\log_{10}[y(\infty) - y] \cong \log_{10}A - \alpha\,(RPM_{FS})\log_{10}e$$

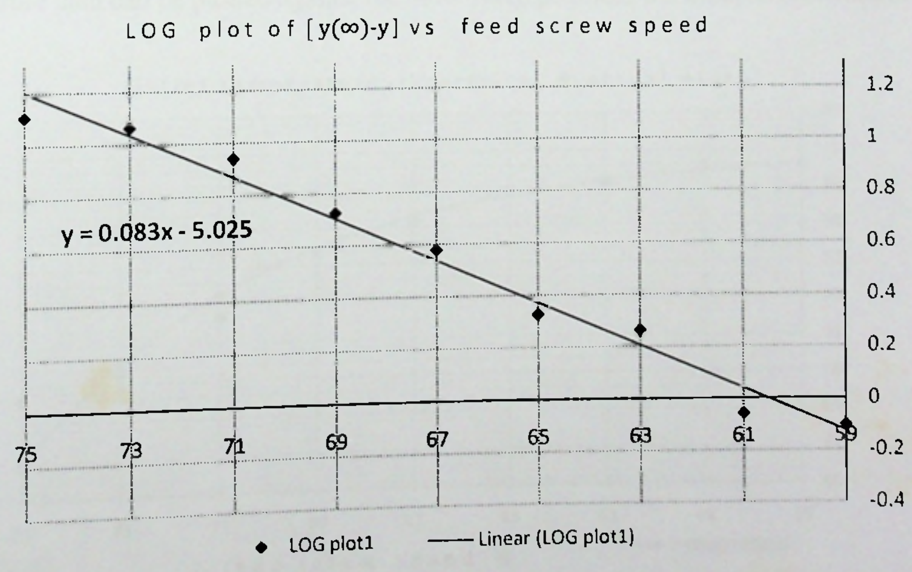


Figure 3.7 The plot of $\log_{10}[y(\infty) - y]$ against RPM_{FS}

$$\log_{10}[T^{100\%}_{out,B_{V,max}} - T^{100\%}_{out,B_V}] \cong \log_{10}A - 0.434\,\alpha\,(RPM_{FS}) \qquad : \text{A is negative}$$

We have taken that $T^{100\%}_{out,B_{V,max}} = 78$

The equation of the trend line is;

$$Y_{trend} = 0.083x - 5.025$$

At $y = 0,\ x = 60.542$

By the comparison of two equations we get,

$$\log_{10}|A| = -5.025$$

$$A = -0.00000944\ ; \qquad \textbf{\textit{A} is negative.}$$

$$-0.434\,\alpha = 0.083$$

$$\alpha = -0.1912$$

The theoretical values of $y - y(\infty) \cong Ae^{-\alpha(RPM_{FS})}$ and the experimental (actual) outlet temperature data can be plotted against the blow valve position, the independent variable

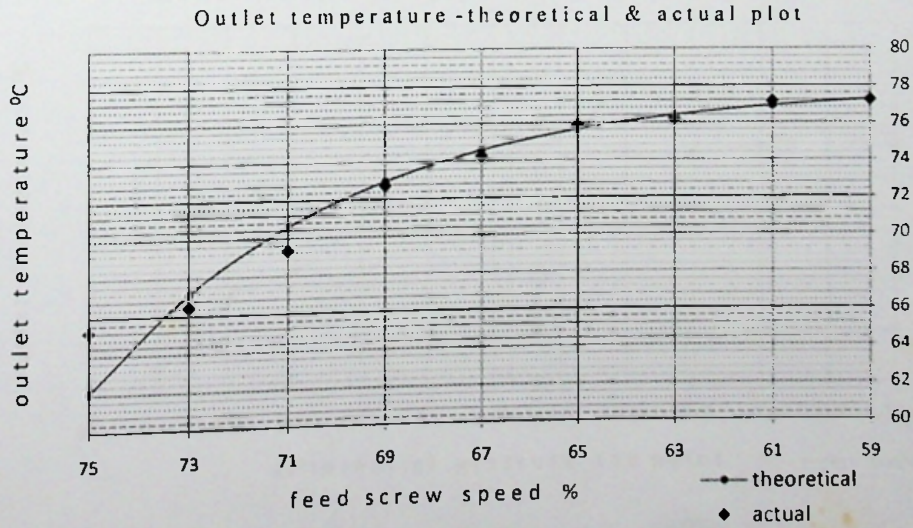


Figure 3.8 Theoretical and experimental plot of outlet temperature against feed screw speed.

So we come to the conclusion that this theoretical plot fairly matches with the experimental plot and the equation of this theoretical plot gives the control relationship of outlet temperature to the feed screw speed when all the other parameters are fixed including the steam PRV.

Then the equation of the control relationship is,

$$y(RPM_{FS}) = y(\infty) + Ae^{-\alpha\, RPM_{FS}}$$

Substituting the values obtain from the plot,

$$T_{outlet}^{100\%}\Big|_{RPM_{FS}} = 78 - 0.00000944\, e^{+\,0.1912(\,RPM_{FS})} \qquad 3.16$$

The control equation of the outlet temperature is a function of feed screw speed when all the other parameters are fixed

The same scenario is gone for the construction of the model of relationship between outlet temperature and differential pressure.

3.2.7 The experimental data plot obtained against the differential pressure set point

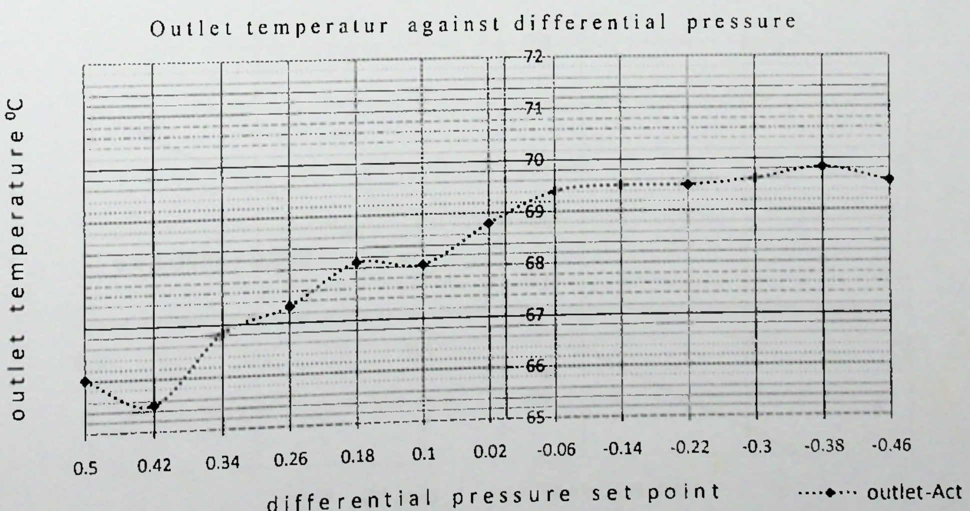


Figure 3.9 The outlet temperature plot against differential pressure(P_{diff}).

Assume that the response is given by a sum of exponentials as in the case of other two variables,

$$y(P_{diff}) = y(\infty) + Ae^{-\alpha P_{diff}} + De^{-\beta P_{diff}} + Fe^{-\gamma P_{diff}} + \cdots \quad 3.17$$

Here $y(\infty)$ will be the maximum value that $T_{outlet}^{100\%}$ can get when differential pressure is in its highest negative value in the situation considered. (The value of differential pressure set point is usually varied in between +0.5 to -0.5. The values going away from it will damage the process and the plant itself.)

Subtracting off the final value of the equation 3.17 and assuming that $-\alpha$ is the slowest pole, it can be written,

$$y - y(\infty) \cong Ae^{-\alpha P_{diff}}$$

By looking at the figure 3.9 let us consider that $y(\infty) \cong 70$ and A is negative since $y(\infty)$ is greater than $y(P_{diff})$. Using the data of figure 3.9 we can plot the graph of $\log_{10}[y(\infty) - y]$. The figure 3.10 shows the data plot of $\log_{10}[y(\infty) - y]$ and from the line fitted to the plot we can determine A and α of the following equation

$$\log_{10}[y(\infty) - y] \cong \log_{10}A - \alpha P_{diff} \log_{10}e$$

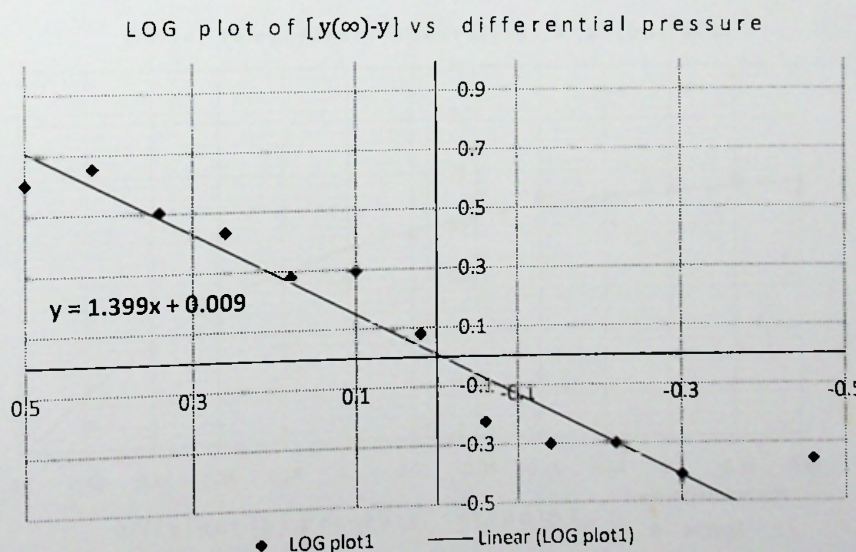


Figure 3.10 The plot of $\log_{10}[y(\infty) - y]$ against P_{diff}

$$\log_{10}\left[T^{100\%}_{out,\,B_{V,max}} - T^{100\%}_{out,\,B_V}\right] \cong \log_{10}A - 0.434\ \alpha\ P_{diff} \qquad : \mathbf{A} \text{ is negative}$$

We have taken that $T^{100\%}_{out,\,B_{V,max}} = 70$

The equation of the trend line is;

$$Y_{trend} = 1.399x + 0.009$$

At $y = 0,\ x = -0.00643$

By the comparison of two equations we get,

$$\log_{10}|A| = 0.009$$

$$A = -1.0209\ ; \qquad A \text{ is negative.}$$

$$-0.434\ \alpha = 1.399$$

$$\alpha = -3.223$$

The theoretical values of $\mathbf{y - y(\infty) \cong Ae^{-\alpha P_{diff}}}$ and the experimental (actual) outlet temperature data can be plotted against the blow valve position, the independent variable

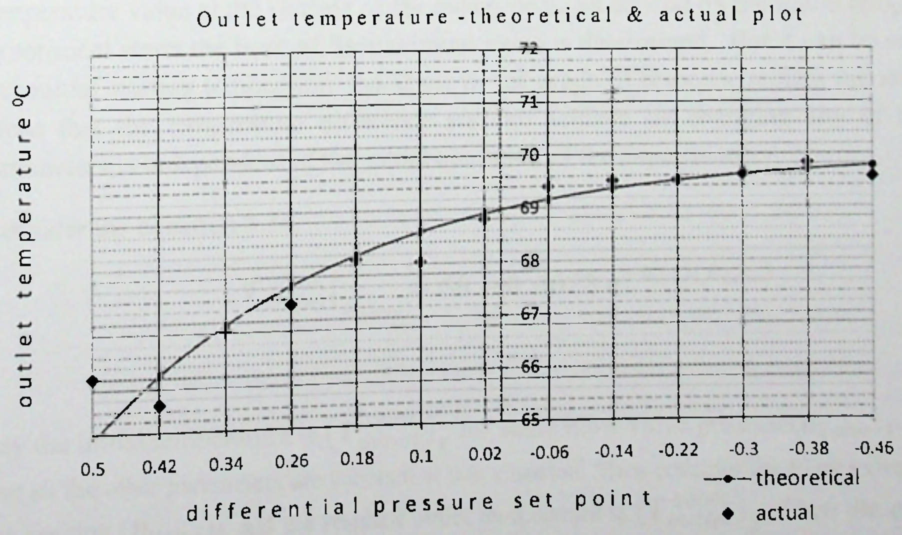


Figure 3.11 Theoretical and experimental plot of outlet temperature against differential pressure.

So we come to the conclusion that this theoretical plot fairly matches with the experimental plot and the equation of this theoretical plot gives the control relationship of outlet temperature to the feed screw speed when all the other parameters are fixed including the steam PRV.

Then the equation of the control relationship is,

$$y(P_{diff}) = y(\infty) + Ae^{-\alpha P_{diff}}$$

Substituting the values obtain from the plot,

$$T^{100\%}_{outlet}\Big|_{P_{diff}} = 70 - 1.0209\ e^{+3.223\ P_{diff}} \qquad 3.18$$

The control equation of the outlet temperature is a function of differential pressure when all the other parameters are fixed.

3.3 The Model for the Temperature Difference

Now let us again consider the equations 3.14, 3.16 and 3.18 obtained for the control variables. Here $y(\infty)$ in every equation is a constant depend on the initial outlet temperature value at the starting of the experiment. So depend on the initial temperature the experiment starts the limit of its maximum value is determined. But it can be seen that for any initial starting temperature the shape of the graph of response remain the same. Which mean that the temperature difference we can achieve by changing any of the control parameters is independent of the initial condition of the experiment.

Consider the equation 3.14,

$$T^{100\%}_{outlet}\Big|_{B_{Valve}} = 68 - 0.0028\ e^{+0.113(B_{Valve})}$$

Say the initial temperature is $\left(T^{100\%}_{outlet}\right)_1$ for some blow valve position$(B_{Valve})_1$. Remember that all the other parameters are constant at this situation. Then consider the blow valve is closed to the position $(B_{Valve})_2$ and the resulted outlet temperature is $\left(T^{100\%}_{outlet}\right)_2$. Then the equations of the model come as follows;

Initial situation;

$$\left(T^{100\%}_{outlet}\right)_1 = 68 - 0.0028\ e^{+0.113(B_{Valve})_1} \qquad 3.19$$

Final situation;

$$\left(T^{100\%}_{outlet}\right)_2 = 68 - 0.0028\, e^{+0.113(B_{Valve})_2} \qquad 3.20$$

Subtracting equation 3.19 from equation 3.20 we get.

$$\left(T^{100\%}_{outlet}\right)_2 - \left(T^{100\%}_{outlet}\right)_1 = 0.0028\left[e^{+0.113(B_{Valve})_1} - e^{+0.113(B_{Valve})_2}\right]$$

$$\Delta T_{B_{Valve}} = 0.0028\left[e^{+0.113(B_{Valve})_1} - e^{+0.113(B_{Valve})_2}\right] \qquad 3.21$$

This is the increment that the outlet temperature can get when the blow valve is closed from some know value. The increment can be easily used to calculate the outlet temperature at which the system is going to be settled as a result of blow valve's known reduction.

In the control system which is under design knows the relationship of outlet temperature to the moisture content of fiber. So the reference value is coming from the moisture side. When the operator has set the moisture set point the cascaded PID system will bring the actual moisture level to that particular set point. If the cascaded PID can do this the multistage second controller would not interfere with him. In the unfortunate situation of 100% steam PRV condition the PID system has to ask help from the multistage controller to hold and bring back the system to the active temperature level. Actually if the outlet temperature remains around the required set value to keep a certain moisture level even if the PRV is 100% open, the multistage controller would not go for the support. Because, the PID would not ask for any help. The reason is that if the system can run without changing the multistage control parameters the output will not get affected. Even though the closing of blow valve does not cause in mass flow reduction, if it is closed beyond the critical value it should be opened for a certain feed screw speed, the feed screw speed has to be reduced in order to maintain the required current level in the main motor.

Now imagine situation when the PRV is 100% open and the outlet temperature has gone down away from the set value. The cascaded PID has already decided the required outlet temperature set point. So the system now knows where the actual temperature is and what the temperature difference is and hence the increment that should be done in order to bring the temperature back. Once the increment is calculated the required control parameter value can be calculated and then command the actuator to get the appropriate action. The equation 3.21 will show how the parameter value is calculated for blow valve after the increment is known.

$$\Delta T_{B_{Valve}} = 0.0028\left[e^{+\,0.113(\,B_{Valve})_1} - e^{+\,0.113(\,B_{Valve})_2}\right]$$

$$e^{+\,0.113(\,B_{Valve})_2} = e^{+\,0.113(\,B_{Valve})_1} - \frac{\Delta T_{B_{Valve}}}{0.0028}$$

$$B_{Valve,2} = \frac{1}{0.113}\ln\left[e^{+\,0.113\,B_{Valve,1}} - \frac{\Delta T_{B_{Valve}}}{0.0028}\right] \quad 3.22$$

The equation 3.22 will determine the new blow valve position for the required increment. And the scaled value of this new blow valve position is the analog signal goes to the blow valve actuator.

Considering the same procedure followed for the blow valve, the control command for the feed screw and the differential pressure can be calculated.

Consider the equation 3.16,

$$T_{outlet}^{100\%}\Big|_{RPM_{FS}} = 78 - 0.00000944\, e^{+\,0.1912(\,RPM_{FS})}$$

The required increment of the outlet temperature to bring back the moisture level is.

$$\Delta T_{RPM_{FS}} = 0.00000944\left[e^{+0.1912\,(\,RPM_{FS})_1} - e^{+\,0.1912\,(\,RPM_{FS})_2}\right] \quad 3.23$$

This is the increment that the outlet temperature can get when the feed screw speed is reduced from some know value. The increment can be easily used to calculate the outlet temperature at which the system is going to be settled as a result of feed speed's known reduction.

$$e^{+0.1912\,(RPM_{FS})_2} = e^{+0.1912\,(RPM_{FS})_1} - \frac{\Delta T_{(RPM_{FS})}}{0.00000944}$$

$$RPM_{FS,2} = \frac{1}{0.1912} \ln\left| e^{+0.1912\,RPM_{FS,1}} - \frac{\Delta T_{(RPM_{FS})}}{0.00000944} \right| \qquad 3.24$$

The equation 3.24 will determine the new feed screw speed for the required temperature increment. And the scaled value of this new feed screw speed is the analog signal goes to the feed screw motor drive.

The same procedure is followed to calculate the analog control signal for the differential pressure valve using the equation 3.18.

$$T_{outlet}^{100\%}\Big|_{P_{diff}} = 70 - 1.0209\ e^{+3.223\,P_{diff}}$$

The required increment of the outlet temperature to bring back the moisture level is,

$$\Delta T_{P_{diff}} = 1.0209\left[e^{+3.223\,(P_{diff})_1} - e^{+3.223\,(P_{diff})_2}\right] \qquad 3.25$$

This is the increment that the outlet temperature can get when the differential pressure is reduced from some know value. The increment can be easily used to calculate the outlet temperature at which the system is going to be settled as a result of known reduction or a negative increment of the differential pressure.

$$e^{+3.223\,(P_{diff})_2} = e^{+3.223\,(P_{diff})_1} - \frac{\Delta T_{P_{diff}}}{1.0209}$$

$$P_{diff,2} = \frac{1}{3.223} \ln\left| e^{+3.223\,P_{diff,1}} - \frac{\Delta T_{P_{diff}}}{1.0209} \right| \qquad 3.26$$

The equation 3.26 will determine the new differential pressure set point for the required temperature increment. And the scaled value of this new differential pressure set point is the analog signal goes to the differential pressure valve.

Even though the outlet temperature has a known relationship with the moisture content of fiber, the new control system consider the set point set by the cascaded PID. The cascaded PID decides the outlet temperature set point depend on how much the actual moisture level deviate from the moisture set point. The more the deviation the higher the temperature set point. The higher the temperature set point the higher will be the temperature increment. For a higher increment higher values will be calculated from the control equations.

In addition to this one more constraint has to be considered in the operation of this system. it is actually a rule that the system has to obey. Although controlling moisture is the most critical job, making good fiber is the reason why they run the refiner.

The amount of main motor current normally indicates how much load that has applied to the fiber inside the grinding house. If we maintain a fix plate gap the bottom pressure or the grinding house pressure decides the main motor current. The pressure increases with the feed screw speed. The increment of pressure increases the current. In high pressure conditions or in other words in high current conditions the fiber becomes so fine which is not suitable for the production. Of course this will reduce the moisture content of fiber. But we do it when there is no other option.

The operators know the relationship of current with the feed screw speed that can produce good fiber.

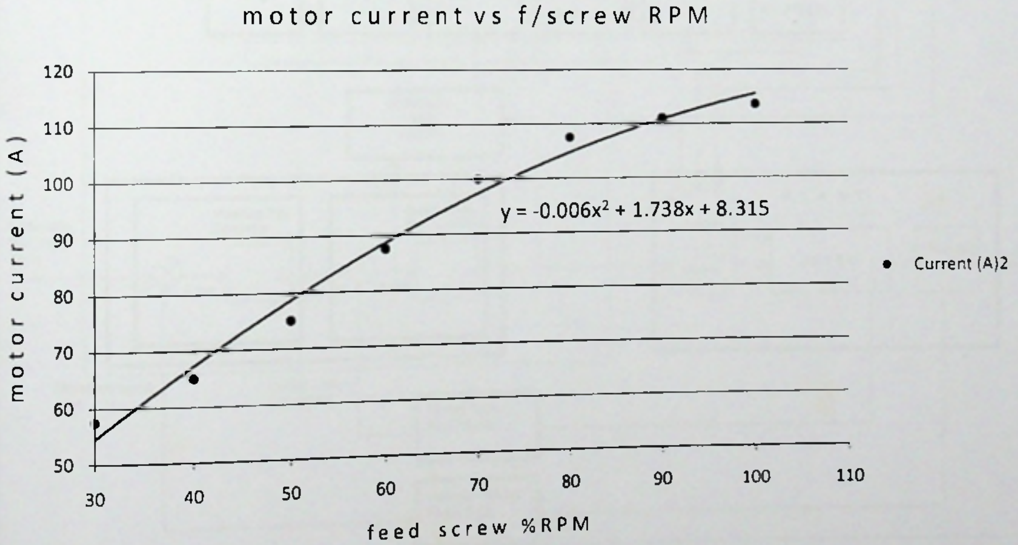


Figure 3.12 The relationship between feed screw speed and motor current is obtained by plotting operator's data.

The relationship between main motor current and feed screw speed is given by the equation

$$y = -0.006x^2 + 1.738x + 8.315$$

Where y = Main motor current
x = Feed screw speed

To maintain this relationship the grinding house pressure should be varied according to the increment of feed screw speed. The grinding house pressure is maintained by regulating the blow valve. It can be seen that every parameter has some interrelationship. Anyway to maintain this current condition the blow valve and the feed screw speed also has a known relationship. To increase outlet temperature we close the blow valve. But it increases the motor current. But we can let it increase by some amount which would not harm to the motor and the system. So if we close the blow valve more and more the feed screw speed has to be reduced under this rule of current.

3.4 The Algorithm

The control outputs of the multistage controller have now been determined and next job is to put them in an algorithm that will continuously scan the system. The control diagram of the control system can be as follows;

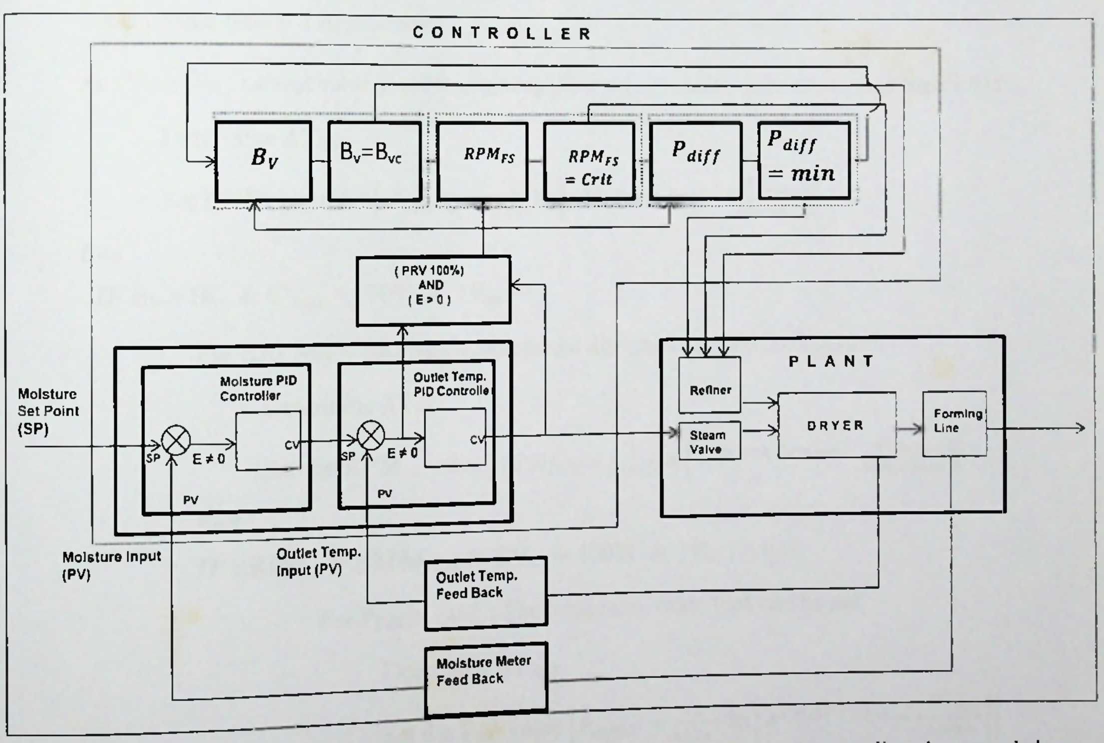


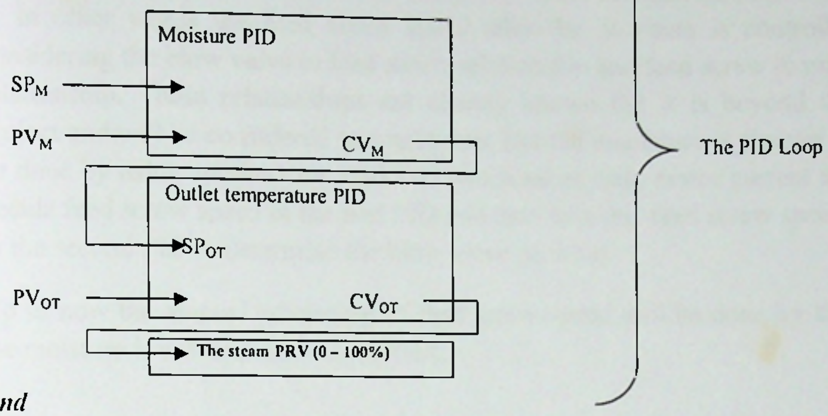
Figure 3.13 The block diagram of the control system. The controller is made by coupling the cascaded PID and the multistage controller.

The algorithm is written under the same conditions and constrains we maintained at the time of derivation of the control equations of each parameter.

Following is the basic Control Algorithm;

For $CV_{OT} < 100\%$ & $|E_M| \geq 0$ $(E_M = SP_M - PV_M)$

The cascaded PID; Loop update time = Scan time of the PLC



End

IF $CV_{OT} = 100\%$ & $|E_M| > 0$ $(E_M = SP_M - PV_M)$

Loop update time = 120 seconds

For $B_V \geq B_{VL}$: Lowest value possible in getting the maximum motor current possible **(figure 3.12)**

Determine $\mathbf{\Delta T_{BV}}$

Set the $\mathbf{B_V}$ position $\left\{ B_{Valve,2} = \frac{1}{0.113} \ln\left[e^{+0.113\, B_{Valve,1}} - \frac{\Delta T\, B_{Valve}}{0.0028} \right] \right\}$

End

IF $B_V > B_{VL}$ & $CV_{OT} = 100\%$ & $|E_M| > 0$

For $\Delta RPM_{FS} \leq \Delta RPM_{FS,M}$ Maximum difference set by the operator

Determine $\mathbf{\Delta T_{FS}}$

Set the $\mathbf{RPM_{FS}}$ value $\left\{ RPM_{FS,2} = \frac{1}{0.1912} \ln\left[e^{+0.1912\, RPM_{FS,1}} - \frac{\Delta T_{(RPM_{FS})}}{0.00000944} \right] \right\}$

End

IF $\Delta RPM_{FS} > \Delta RPM_{FS,M}$ & $CV_{OT} = 100\%$ & $|E_M| > 0$

For $P_{Diff} \geq -0.5$: The minimum value that can be set

Determine $\mathbf{\Delta T_{Diff}}$

Set the $\mathbf{P_{Diff}}$ value $\left\{ P_{diff,2} = \frac{1}{3.223} \ln\left[e^{+3.223\, P_{diff,1}} - \frac{\Delta T_{P_{diff}}}{1.0209} \right] \right\}$

End

ELSE

RETURN

ELSE

RETURN

ELSE

RETURN

This basic algorithm can be used to write the PLC program which will contain hundreds of logical interlocks and techniques that would control moisture content of fiber. After all the parameters are reduced to get the moisture level back to normal these parameters has to be once again increased to increase the production rate. The increment of the production rate or in other words the feed screw speed after the moisture is controlled can be done considering the blow valve to feed screw relationship and feed screw to main motor current relationship. These relationships are already known but it is beyond the scope of this project and will be considered as a next step. But the procedure is simpler than this and can be done by using another cascaded PID which takes main motor current as the set-point to decide feed screw speed in the first PID and then take this feed screw speed as the set-point in the second PID to determine the blow valve position.

Up to now the manual advancing of feed screw speed will be done by the operators after the moisture is automatically controlled.

Chapter 4

Application & Results

In Merbok up to now only the program of the cascaded PID system was attached to the main program. The coding of multistage controller has to be coupled to the PID program later. The HMI of the PID has to be designed so as to be easily understood by the operators and has to be included all their requirements.

In Merbok, in the sense of automation, Rockwell Automation plays the biggest role. More than 90% of the plant was automated using Rockwell software and Allen Bradley controllers. The moisture PID program was inserted to the controller which handles most of the refiner area analog signals and control structures.

The PID program is written using the standard programming language RSLogix500 developed by Rockwell Automation as the programming language for the Allen Bradley controller SLC5. The SLC5 is a high standard PLC developed by Allen Bradley and one of the latest in the family of Allen Bradley processors.

The PID controller works pretty well for more than three months and has proved that automatic control is more accurate than the human control.

Anyway the concept of fully automatic moisture control was established to the first time in Merbok after six years of Plant history where it seemed little strange to the operators to absorb the concept and get rid of the old manual control system. The reason was that the operators never thought that this can be done or modeled theoretically due the complex nature of the controlling pattern. Now it is almost three months passed and they cannot run without it.

The graphical representation of the HMI has to be changed several times to give the operators, a better one and several modifications with many interlocks have to be inserted to the control program. Playing with dryer is a critical job since the high temperature levels in the dryer can cause fire inside it. So control interlocks and safety alarming has to be set in the relevant places of the program to minimize the fire risk.

4.1 Tuning the PIDs

The gains of the PID system were tuned using the instructions provided by RSLogix500 software. It was mentioned in section 3.1.3 and no other tuning criterion was used. But the second PID of the cascaded system cannot be tuned using this method and has to be tried with free hand to get a better control in moisture.

The following figures show the structured files of the PID settings. The first one is the Moisture PID.

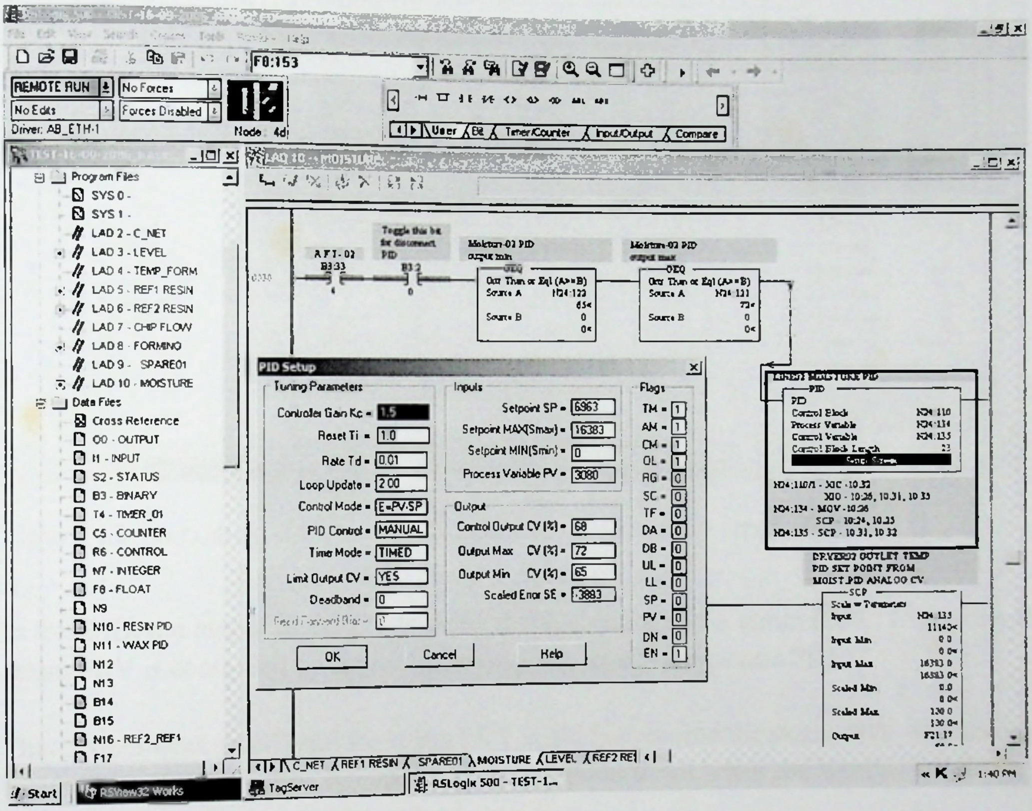


Figure 4.1 The Moisture PID, the first PID of the cascaded PID.

In the PID setup screen, the first three fields belong to the gains of the PID where the values can be entered in the process of tuning. Here the PID output (CV) is going to the set point of the second PID which is the outlet temperature set point.

The outlet-temperature PID. The second PID of the cascaded system.

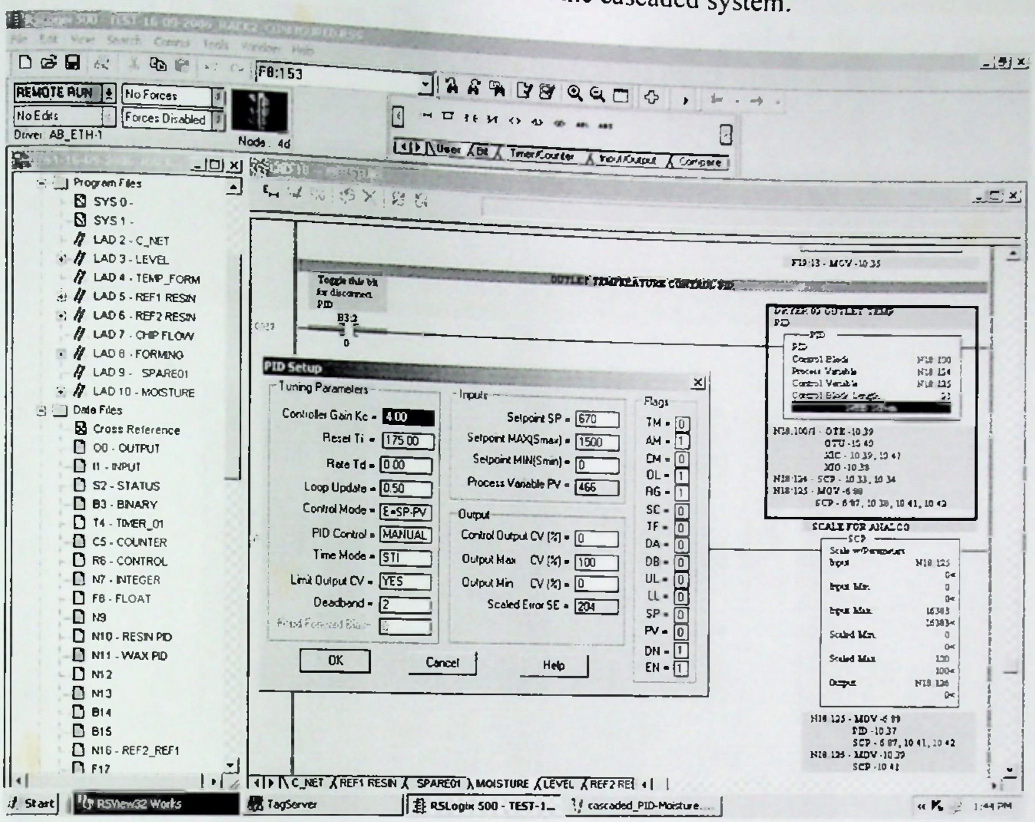


Figure 4.2 The Outlet Temperature PID, the second PID of the cascaded PID.

In this PID, the output or the CV is going to the actuator of the steam PRV. Ultimately the steam PRV is controlled by the moisture set point set at the moisture PID.

This system works well until the steam PRV is 100% open and the steam PRV will never go to 100% until the weather is good. It all goes upside down when the weather condition is not favorable to the temperature control.

All the data that should be monitored are taken to graphical trends using RSView32; the same graphic software used to build all the other HMIs of SCADA, and logged in data files. So history is always retrievable where we can trace any situation in the past to reorganize or modify the system. These trends played a major role in the process of tuning PIDs.

The following figure shows the cascaded PID system and the restrictions inserted with it as requested by the operators. The restrictions are actually used for the safety reasons which mean that the parameters do not move beyond the limits which are entered.

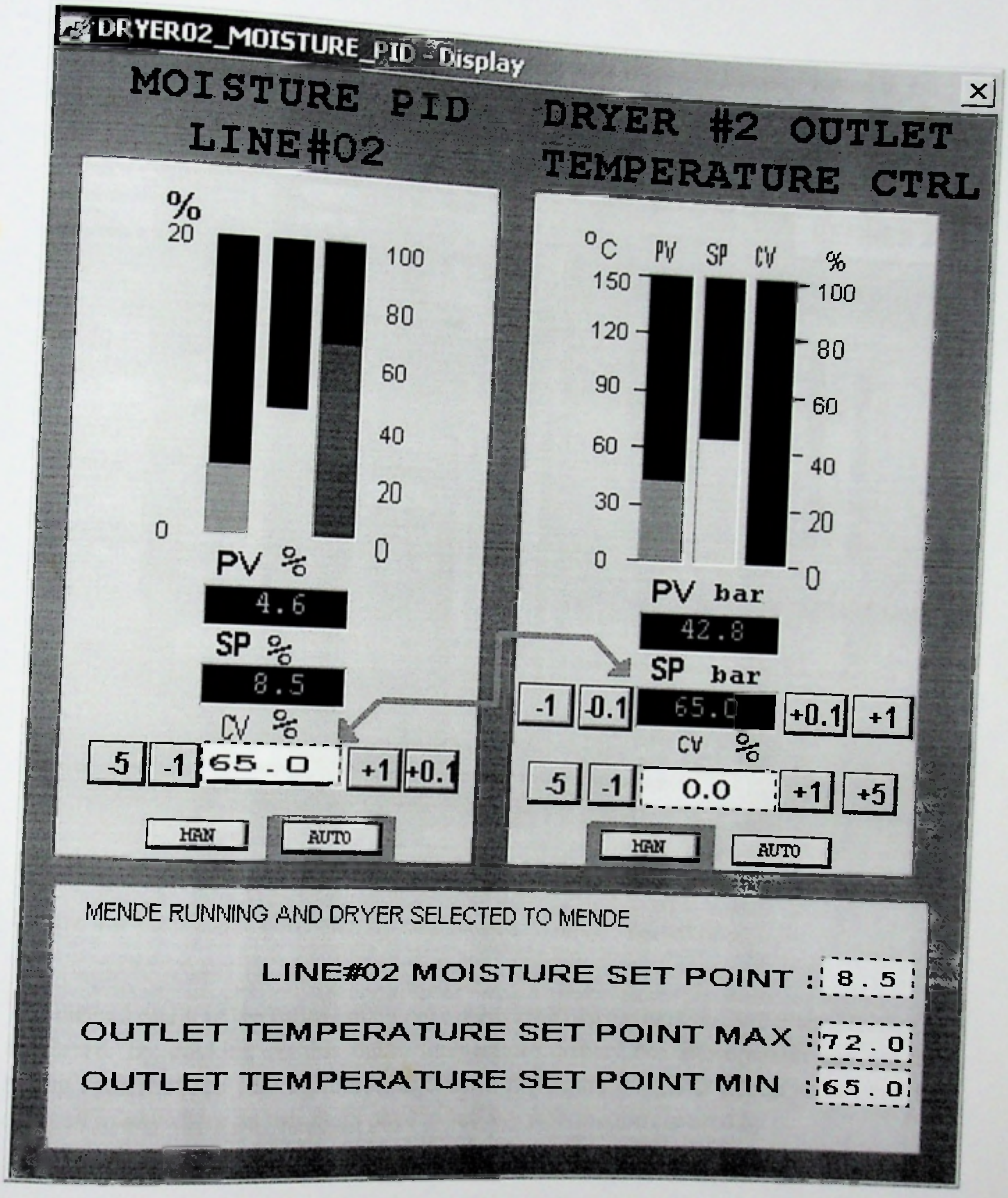


Figure 4.3 The Cascaded PID. The moisture and the outlet temperature PIDs are cascaded.

The green arrow shows the relationship between the control variable of moisture PID and the set point of the outlet temperature PID. Actually they were made equal in this controller.

The maximum value and minimum value of the outlet temperature can be set by the refiner operators to define the range of variation of the outlet temperature and this setting will be written in maximum and minimum output fields of the moisture PID setup file. This will restrict the

The following figure shows how the above PID system comes as a popup screen in the refiner main page HMI.

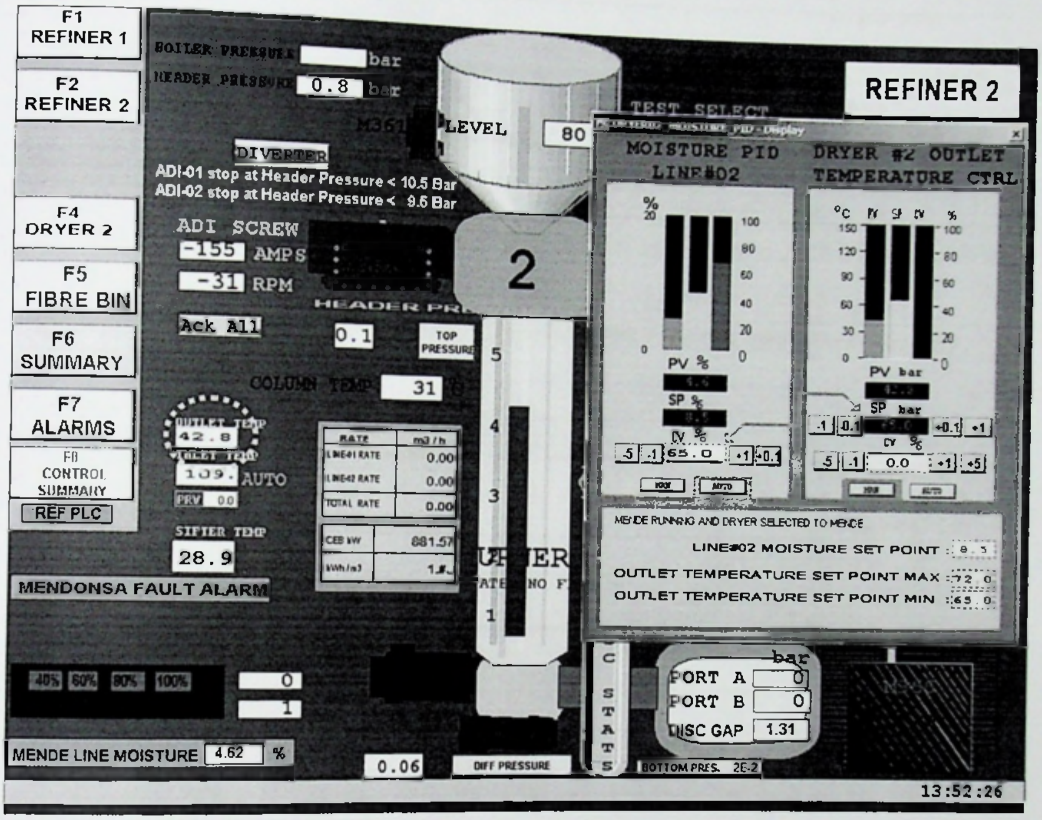


Figure 4.4 The popup screen of PID. The background is the refiner main screen.

The dashed circle in the refiner main page shows the place where the outlet temperature is displayed. By clicking on this outlet temperature display box the operator can get the popup screen of the PID system as shown in the figure 4.4. This popup screen can be dragged to anywhere on this main page to see any information covered by it.

4.2 The Results

The trends of all the variables considered are plotted in the SCADA and can be considered as the results of this project. A one general situation of moisture control has been considered in the discussion of results.

A general situation of moisture control process using the cascade PID system.

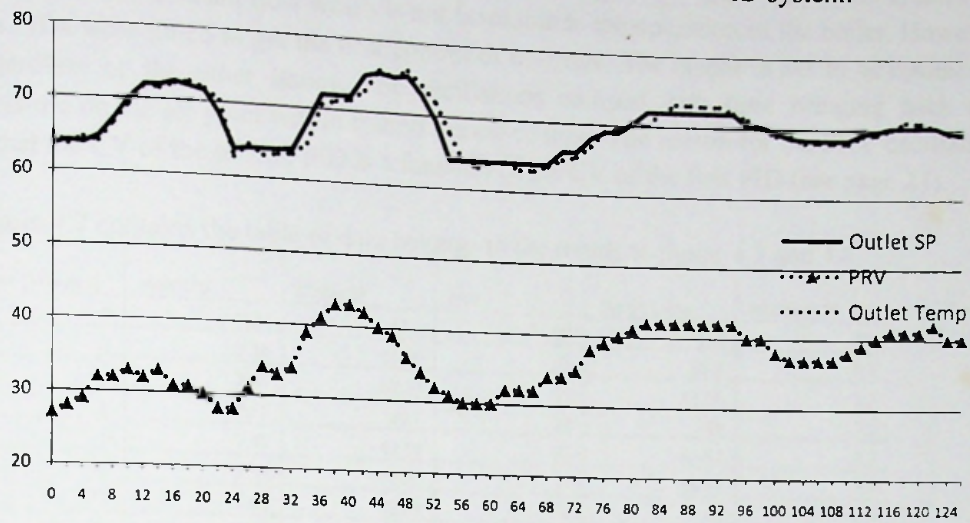


Figure 4.5 Outlet temperature, Outlet temperature set point, PRV position against time (Minutes).

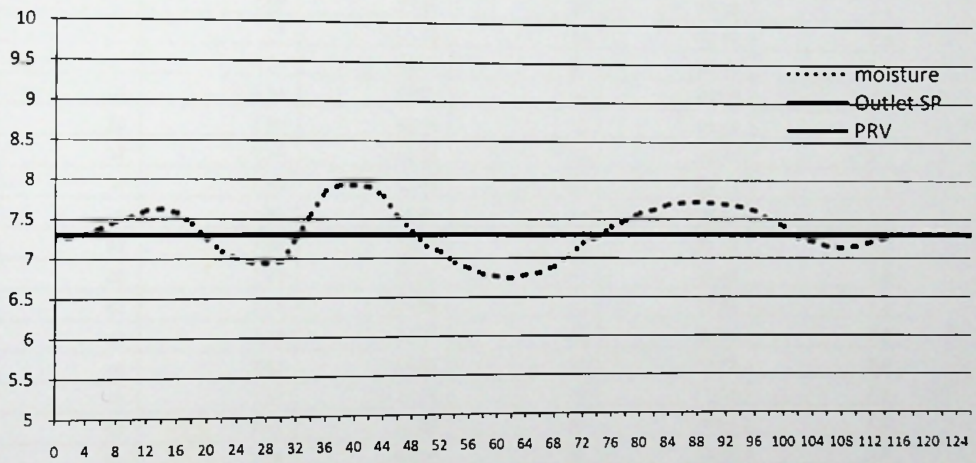


Figure 4.6 The response of Moisture and the Moisture set point against time (Minutes).

Figure 4.5 shows the how the outlet temperature set point is increased to compensate the increment of moisture (in figure 4.6) from its set point. The plot in figure 4.5 shows that the outlet temperature has nicely followed its set point path defined by the moisture PID. The outlet temperature set point (SP) is the CV of moisture PID. In the figure, the CV of moisture PID (cannot see) was overlapped by the set point of outlet temperature since they are equal quantities. It can be seen that the steam PRV position has increased due to the increment of outlet temperature set point to drop down the moisture content and vice versa.

The oscillation of the steam PRV is not good for the process. This oscillation creates an oscillation in the steam flow which is not favorable to the operation of the boiler. However the PIDs were tuned to get the best control of moisture. The response has to be optimized regardless of the other issues. The oscillations damped with time bringing back the moisture on the set point within a short period of time. The reason for the PRV oscillation is that the CV of the second PID is a function of the CV of the first PID (see page 21).

Figure 4.7 contains the table of data belongs to the trends at figure 4.5 and 4.6

Time (Minutes)	moisture	Outlet SP	PRV	Outlet Temp	Moisture SP
0	7.24	63.5	27	64.8	7.3
2	7.26	63.99	28	63.5	7.3
4	7.31	63.77	29	64.46	7.3
6	7.38	64.7	32	64	7.3
8	7.47	67.16	32	66.62	7.3
10	7.53	69.99	33	69.25	7.3
12	7.61	71.99	32	71.86	7.3
14	7.63	71.99	33	71.5	7.3
16	7.58	72.49	31	72.2	7.3
18	7.44	71.99	31	72.6	7.3
20	7.24	71.46	30	71.75	7.3
22	7.09	68.35	28	70.15	7.3
24	7	63.72	28	62.62	7.3
26	6.95	63.99	31	64.44	7.3
28	6.94	63.99	34	63.03	7.3
30	6.96	63.99	33	63.34	7.3
32	7.26	64.13	34	63.45	7.3
34	7.56	67.96	39	65.05	7.3
36	7.86	71.99	41	70.62	7.3
38	7.93	71.99	43	71.15	7.3
40	7.93	71.99	43	71.42	7.3
42	7.91	74.99	42	72.88	7.3
44	7.79	75.44	40	75.86	7.3
46	7.52	74.99	39	74.98	7.3
48	7.34	75.24	36	76.04	7.3
50	7.15	72.69	34	74.1	7.3
52	7.08	69.26	32	71.76	7.3
54	6.94	63.96	31	67.58	7.3
56	6.87	63.99	30	63.74	7.3
58	6.79	63.99	30	63.12	7.3
60	6.76	63.99	30	63.89	7.3
62	6.74	63.99	32	63.99	7.3
64	6.78	63.99	32	63.04	7.3
66	6.81	63.99	32	63.05	7.3
68	6.89	63.99	34	63.77	7.3
70	7.02	65.95	34	64.79	7.3
72	7.19	65.97	35	65.25	7.3
74	7.26	67.96	38	66.86	7.3
76	7.4	68.95	39	69.03	7.3
78	7.48	68.95	40	69.56	7.3

Figure 4.7 Table of data of a general situation of moisture control. Continue to page 55.

80	7.58	70.35	41	70.11	7.3
82	7.62	71.99	42	70.14	7.3
84	7.69	71.99	42	71.99	7.3
86	7.71	71.99	42	73.13	7.3
88	7.72	71.99	42	73.1	7.3
90	7.71	71.99	42	72.99	7.3
92	7.69	71.99	42	72.98	7.3
94	7.66	71.99	42	72.11	7.3
96	7.61	70.25	40	71.23	7.3
98	7.49	70.25	40	70.01	7.3
100	7.41	69.39	38	68.99	7.3
102	7.25	68.65	37	69.01	7.3
104	7.21	68.45	37	67.99	7.3
106	7.15	68.4	37	68.06	7.3
108	7.13	68.4	37	67.99	7.3
110	7.15	68.4	38	67.96	7.3
112	7.2	69.32	39	69.02	7.3
114	7.25	69.66	40	69.21	7.3
116	7.31	70.21	41	69.99	7.3
118	7.32	70.21	41	71.01	7.3
120	7.33	70.21	41	70.86	7.3
122	7.32	70.25	42	70.25	7.3
124	7.31	69.48	40	69.38	7.3
126	7.28	69.24	40	69.21	7.3

Figure 4.7 Table of data of a general situation of moisture control. Continued from Page 55.

Chapter 5

Conclusion

The cascaded PID that has already been implemented carry out the job with reasonable accuracy that cannot be achieved by manually. It has been proved without dispute that automatic control is more accurate than the human control.

Now more than three months has passed and no complain on the reliability or any incompatibility with the prevailing system has been reported.

The PID system as it was predicted gave the expected solution to the problem of board splitting due to high or low moisture. The expected saving as it was estimated is around six million rupees. The important thing gained after the implementation of this fully automatic system is the ability to maintain the consistency of the plant. The consistency gives time to identify other minor problems of the plant which cannot be monitored with inconsistent situations. This has smoothed the production process and considerably improved the quality of the product. The most serious quality issue comes when a split board has reached the customer without been detected by the quality controller. If the split is in the mid of the board how can the quality controller check it. If we do not have a scanner, the middle area splitting can hardly be detected. This has brought a very bad reputation and now the Merbok has got rid of it.

The addition of resin quantity for a unit production has been fixed after the smooth control of moisture and could save millions of money wasted for additional resin usage. The resin usage for the production has to be increased always to stop the splitting problem by increasing the bond in between fibers of the board. The additional bond is totally unnecessary because it is beyond the specification of the product. We cannot sell the boards to a higher price by telling that we have used additional resin inside them. In fiber board industry resins only second to the wood when consider the cost of raw materials. So saving resin by smooth control of moisture is one of the biggest achievements and it could fix the resin usage to a value of around $90kg/1m^3$ from a value of around $120kg/1m^3$.

The overall improvement of the production and the whole process of fiber board manufacturing, after the automatic control of fiber moisture content, cannot be easily measured and it is always something more than that can be measured. It has made the life of both refiner and press operators easy due to the abandonment of a time wasting and irritating job they have done on removing the reject boards from the production line.

The second multistage controller will be coupled to the PID and hope that it will control the moisture level under situations where the cascaded PID cannot achieve it.

The multistage controller has to be implemented in a processor that can handle enough analog inputs and outputs and can perform all mathematical functions derived at the modeling. The same PLC used for the PID system can be used for this controller and if there are no additional I/Os available, new I/O cards can be inserted to the same rack available or to an expansion rack.

References

[1] Clarence W. de Silva, "Mechatronics – An Integrated Approach", CRC Press, 2000.

[2] Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, "Feedback Control of Dynamic Systems, Fourth Edition, Pearson Education Inc, 2002.

[3] D. S. Mathur, "Mechanics", Vikas Publishing House (Pvt) Ltd., 1978.

[4] I. V. Savelyev, "Physics – Mechanics and Molecular Physics: A General Course", English Translation by Mir Publishers, 1980.

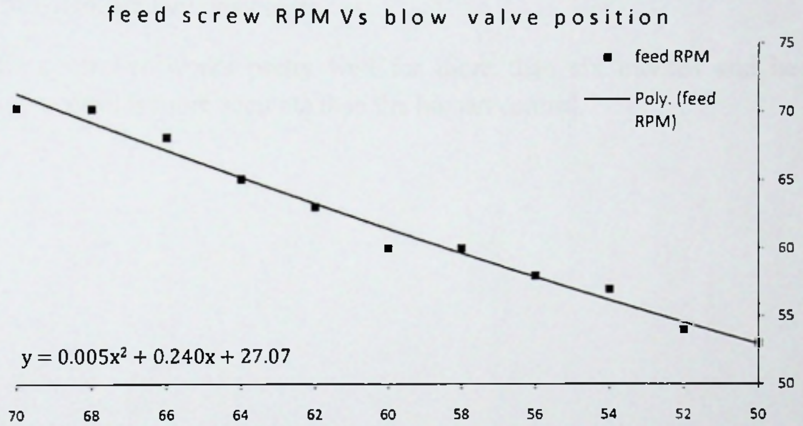
[5] Erwin Kreyszig, "Advanced Engineering Mathematics", Eighth Edition, John Wiley & Sons, Inc, 1999.

Appendix A

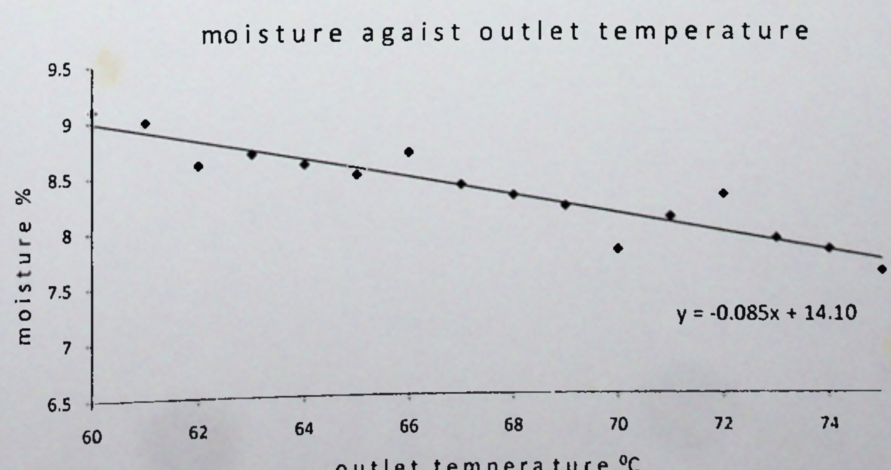
Additional Relationships

If the change of blow valve is high it relates to the feed screw speed. So a relationship can be derived for the amount of change in blow valve and the amount of change in the feed screw speed.

Here the amount of change of blow valve ΔB_{valve} can be related to ΔRPM_{FS}



The following chart shows the relationship between outlet temperature and the moisture content. The experimental data seems go outside the line but maintaining the linearity of the relationship.



Appendix B

Program of the cascaded PID

The program written for the cascaded PID system is attached here. The program is written using the standard programming language RSLogix500 developed by Rockwell Automation as the programming language for the Allen Bradley controller SLC5. The SLC5 is a high standard PLC developed by Allen Bradley and one of the latest in the family of Allen Bradley processors.

The PID controller works pretty well for more than six months and has proved that automatic control is more accurate than the human control.

REFINER 01 MOISTURE CONTROL WITH CASCADE PID SYSTEM

CHANGED MANUAL CONTROL OF MOISTURE INTO AUTOMATIC CONTROL USING A CASCADE PID SYSTEM ON 22-07-2008

```
0000   A F I - 02                                   SCALED PV FROM THE
       B3:33                                        MOISTURE ROW INPUT
      --] [------------------------------------------ SCP
         4                                          Scale w/Parameters
                                                    Input            I:10.7
                                                                      9508<
                                                    Input Min.         4000
                                                                      4000<
                                                    Input Max.        20000
                                                                     20000<
                                                    Scaled Min.           0
                                                                         0<
                                                    Scaled Max.       16383
                                                                     16383<
                                                    Output          N24:104
                                                                      5428<

0001   A F I - 02                                   LINE 01 MOISTURE
       B3:33                                        CONTENT TO HMI
      --] [------------------------------------------ SCP
         4                                          Scale w/Parameters
                                                    Input           N24:104
                                                                      5428<
                                                    Input Min.          0.0
                                                                       0.0<
                                                    Input Max.      16383.0
                                                                   16383.0<
                                                    Scaled Min.         0.0
                                                                       0.0<
                                                    Scaled Max.        20.0
                                                                      20.0<
                                                    Output            F8:93
                                                                 6.699628<

0002   A F I - 02                                   LINE01 MOISTURE
       B3:33                                        SET POINT TO PID
      --] [------------------------------------------ SCP
         4                                          Scale w/Parameters
                                                    Input            F21:19
                                                                       8.5<
                                                    Input Min.          0.0
                                                                       0.0<
                                                    Input Max.         20.0
                                                                      20.0<
                                                    Scaled Min.         0.0
                                                                       0.0<
                                                    Scaled Max.     16383.0
                                                                   16383.0<
                                                    Output           N24:82
                                                                      6963<

0003   REF-01 OUTLET TEMP.                          Moisture-01 pid
       MAX SETPOINT                                 out-put max
       GRT                                          MOV
       Greater Than (A>B)                           Move
       Source A    N24:210                          Source N24:210
                       72<                                     72<
       Source B    N24:211                          Dest    N24:91
                       69<                                     72<

                                                    Moisture-01 pid
                                                    out-put min
                                                    MOV
                                                    Move
                                                    Source N24:211
                                                                   69<
                                                    Dest    N24:92
                                                                   69<

                       Toggle this bit
                       for disconnect
0004   A F I - 02      PID                          LINE#01 MOISTURE PID
       B3:33           B3:2                         PID
      --] [-----------] [---------------------------- PID
         4               0                          Control Block          N24:80
                                                    Process Variable      N24:104
                                                    Control Variable      N24:105
                                                    Control Block Length       23
                                                            Setup Screen

                                                    DRYER01 OUTLET TEMP
                       LINE01 MOISTURE PID          PID SET POINT FROM
0005   A F I - 02      AUTO/MANUAL                  MOIST.PID ANALOG CV.
       B3:33           N24:80                       SCP
      --] [-----------]/[---------------------------- Scale w/Parameters
         4               1                          Input           N24:105
                                                                     11304<
                                                    Input Min.          0.0
                                                                       0.0<
                                                    Input Max.      16383.0
                                                                   16383.0<
                                                    Scaled Min.         0.0
                                                                       0.0<
                                                    Scaled Max.       100.0
                                                                     100.0<
                                                    Output           F21:18
                                                                 68.99835<
```

```
        A F I - 02    LINE01 MOISTURE PID                         LINE01 MOISTURE PID
         B3:33        AUTO/MANUAL                                 RAW CONTROL CV.
0006                     N24:80                                      SCP
        ----] [-----------] [-------------------------------+--------------------------+--
            4             1                                 | Scale w/Parameters       |
                                                            | Input            F21:18  |
                                                            |               68.99835<  |
                                                            | Input Min.          0.0  |
                                                            |                    0.0<  |
                                                            | Input Max.        100.0  |
                                                            |                  100.0<  |
                                                            | Scaled Min.         0.0  |
                                                            |                    0.0<  |
                                                            | Scaled Max.     16383.0  |
                                                            |                16383.0<  |
                                                            | Output          N24:105  |
                                                            |                  11304<  |
                                                            +--------------------------+
```

DRYER-01 OUTLET TEMPERATURE PID CONTROL VIA MOISTURE PID ----22-07-2008
DRYER-01 OUTLET TEMPERATURE INPUT FROM RTD

0007

DRYER 01 SCALED INPUT FROM RTD TO PID PV

SCP
Scale w/Parameters
Input I:6.0
10245<
Input Min. 4000
4000<
Input Max. 20000
20000<
Scaled Min. 0
0<
Scaled Max. 16383
16383<
Output N20:124
6445<

0008

DRYER-01 OUTLET TEMPERATURE TO HMI

SCP
Scale w/Parameters
Input I:6.0
10245<
Input Min. 4000.0
4000.0<
Input Max. 20000.0
20000.0<
Scaled Min. 0.0
0.0<
Scaled Max. 150.0
150.0<
Output F21:3
59.12813<

DRYER 01 OUTLET TERMPERATURE CONTROL FROM SIFTER RTD

0009

DRYER-01 OUTLET TEMPERATURE TO HMI

GRT
Greater Than (A>B)
Source A F21:3
59.12813<
Source B 85.0
85.0<

B14:1 ( ) 12

0010

B14:1] [12

TON
Timer On Delay
Timer T4:2
Time Base 1.0
Preset 60<
Accum 0<
(EN) (DN)

0011

T4:2] [DN

B14:1 ( ) 13

0012

DRYER 01 SCALED PV TO HMI

SCP
Scale w/Parameters
Input N20:124
6445<
Input Min. 0.0
0.0<
Input Max. 16383.0
16383.0<
Scaled Min. 0.0
0.0<
Scaled Max. 150.0
150.0<
Output F21:2
59.12836<

0013

LINE01 MOISTURE PID AUTO/MANUAL
N24:80]/[1

MOV
Move
Source F21:18
68.99835<
Dest F21:13
68.99835<

0014

PID CONTROL BLOCK SETPOINT(CAL. FROM HMI)

CPT
Compute
Dest N20:102
690<
Expression F21:13 * 10.0

DRYER 01 OUTLET TEMPERATURE PID

0015
Toggle this bit for disconnect PID
B3:2
0
DRYER01 OUTLET TEMPERATURE PID
PID
PID
Control Block N20:100
Process Variable N20:124
Control Variable N20:125
Control Block Length 23
Setup Screen

0016
DRYER1 OUTLET TEMP MANUAL SELECT
N20:100
1
SCALED ANALOG OUT TO HMI(DRYER 01)
SCP
Scale w/Parameters
Input N20:125
0<
Input Min. 0
0<
Input Max. 16383
16383<
Scaled Min. 0
0<
Scaled Max. 100
100<
Output N20:126
0<

0017
(DRYER1 & RUN) = 1
(STRUP & TEST) = 0
(DERIVED FROM PLC3)
B3:10
0
DRYER01 OUTLET PID AUTO/MANUAL SELECT (AUTO=1 / MANUAL=0)
B3:3
3
DRYER01 OUTLET PID AUTO/MANUAL SELECT (AUTO=1 / MANUAL=0)
B3:3
3
DRYER1 OUTLET TEMP MANUAL SELECT
N20:100
1
ONE SHOT -REF01 OUTLET TEMP. CONTROL
B3:3
6
DRY01 OUTLET TEMP-PID-CV AUTO REDUCING AT PID MANUAL POS.
TON
Timer On Delay EN
Timer T4:21
Time Base 0.01 DN
Preset 100<
Accum 0<
DRYER1 OUTLET TEMP MANUAL SELECT
N20:100
1
DRYER01 OUTLET PID AUTO/MANUAL SELECT (AUTO=1 / MANUAL=0)
B3:3
3
DRY01 OUTLET TEMP-PID-CV AUTO REDUCING AT PID MANUAL POS.
T4:21
EN
SCALED ANALOG OUT TO HMI(DRYER 01)
MOV
Move
Source 10
10<
Dest N20:126
0<
ONE SHOT -REF01 OUTLET TEMP. CONTROL
B3:3
6

0018
DRYER01 OUTLET PID AUTO/MANUAL SELECT (AUTO=1 / MANUAL=0)
B3:3
3
(DRYER1 & RUN) = 1
(STRUP & TEST) = 0
(DERIVED FROM PLC3)
B3:10
0
DRYER1 OUTLET TEMP MANUAL SELECT
N20:100
U
1

0019
DRYER1 OUTLET TEMP MANUAL SELECT
N20:100
1
DRYER 01 CONTROL VARIABLE (PID)
SCP
Scale w/Parameters
Input N20:126
0<
Input Min. 0
0<
Input Max. 100
100<
Scaled Min. 0
0<
Scaled Max. 16383
16383<
Output N20:128
0<

0020
DRYER 1 OUTLET TEMPERATURE CONTROL PRV POSITION LIMIT BY N20:139
SCALED ANALOG OUT TO HMI(DRYER 01)
GEQ
Grtr Than or Eql (A>=B)
Source A N20:126
0<
Source B N20:139
100<
SCALED ANALOG OUT TO HMI(DRYER 01)
MOV
Move
Source N20:139
100<
Dest N20:126
0<

0021

DRYER#01 STEAM
STATION PRV
OUTPUT

SCP
Scale w/Parameters

Input	N20:125 0<
Input Min.	0 0<
Input Max.	16383 16383<
Scaled Min.	6250 6250<
Scaled Max.	31200 31200<
Output	O:19.1 6250<

REFINER 02 MOISTURE CONTROL WITH A CASCADE PID SYSTEM

CHANGED MANUAL CONTROL OF MOISTURE INTO AUTOMATIC CONTROL USING A CASCADE PID SYSTEM ON
22-07-2008

0022

N24:140 (U) 15

0023

MSG
Read/Write Message (EN)
Type Peer-To-Peer
Read/Write Read (DN)
Target Device 500CPU
Local/Remote Local (ER)
Control Block N24:140
Control Block Length 51
Setup Screen

0024

A F I - 02 B3:33 4 — REF2 FEED TO MENDE I:3 2 1746-IB32

SCALED PV FROM THE MOISTURE ROW INPUT (MSG FROM TXPFRM)
SCP
Scale w/Parameters
Input N24:200 730<
Input Min. 0 0<
Input Max. 2000 2000<
Scaled Min. 0 0<
Scaled Max. 16383 16383<
Output N24:134 5980<

0025

A F I - 02 B3:33 4

LINE-02 MOISTURE CONTENT TO HMI
SCP
Scale w/Parameters
Input N24:134 5980<
Input Min. 0.0 0.0<
Input Max. 16383.0 16383.0<
Scaled Min. 0.0 0.0<
Scaled Max. 20.0 20.0<
Output F8:159 7.300251<

0026

LINE-02 MOISTURE PID AUTO/ MANUAL N24:110 1

MENDE TRIM BELT STOP MSG=>PRSLIN-->TXPFRM TEST<--| (MENDE LINE STOP) N24:201 0

MENDE PRES UNCOUPLED MSG=>PRSLIN-->TXPFRM TEST<--| (MENDE LINE STOP) N24:202 0

REF2 FEED TO LINE 01 I:3 3 1746-IB32

REF2 FEED TO MENDE I:3 2 1746-IB32

MOV
Move
Source F21:19 8.5<
Dest F8:180 8.1<

Moisture-02 PID output max
CPT
Compute
Dest N24:121 68<
Expression N24:210 + 5

Moisture-02 PID output min
CPT
Compute
Dest N24:122 66<
Expression N24:211 + 5

SCALED PV FROM THE MOISTURE ROW INPUT (MSG FROM TXPFRM)
MOV
Move
Source N24:104 5428<
Dest N24:134 5980<

0027

REF2 FEED TO MENDE
I:3
2
1746-IB32

REF-02 OUTLET TEMP. MAX SETPOINT
GRT
Greater Than (A>B)
Source A N24:212
68<
Source B N24:213
66<

MOV
Move
Source F8:158
8.1<
Dest F8:180
8.1<

Moisture-02 PID output max
MOV
Move
Source N24:212
68<
Dest N24:121
68<

Moisture-02 PID output min
MOV
Move
Source N24:213
66<
Dest N24:122
66<

0028

A F I - 02
B3:33
4

LINE-02 MOISTURE SET POINT FROM HMI
SCP
Scale w/Parameters
Input F8:180
8.1<
Input Min. 0.0
0.0<
Input Max. 20.0
20.0<
Scaled Min. 0.0
0.0<
Scaled Max. 16383.0
16383.0<
Output N24:112
6635<

0029

A F I - 02
B3:33
4

Toggle this bit for disconnect PID
B3:2
0

LINE02 MOISTURE PID
PID
PID
Control Block N24:110
Process Variable N24:134
Control Variable N24:135
Control Block Length 23
Setup Screen

0030

A F I - 02
B3:33
4

LINE-02 MOISTURE PID AUTO/ MANUAL
N24:110
1

DRYER02 OUTLET TEMP PID SET POINT FROM MOIST.PID ANALOG CV.
SCP
Scale w/Parameters
Input N24:135
10812<
Input Min. 0.0
0.0<
Input Max. 16383.0
16383.0<
Scaled Min. 0.0
0.0<
Scaled Max. 100.0
100.0<
Output F21:17
65.99524<

0031

A F I - 02
B3:33
4

LINE-02 MOISTURE PID AUTO/ MANUAL
N24:110
1

LINE02 MOISTURE PID RAW CONTROL CV.
SCP
Scale w/Parameters
Input F21:17
65.99524<
Input Min. 0.0
0.0<
Input Max. 100.0
100.0<
Scaled Min. 0.0
0.0<
Scaled Max. 16383.0
16383.0<
Output N24:135
10812<

0032

SIFTER TEMPERATURE IS USED TO CONTROL THE OUT TEMPERATURE OF THE DRYER

DRYER#2 OUTLET TEMP FOR PID_PV
SCP
Scale w/Parameters
Input I:6.1
11324<
Input Min. 4000
4000<
Input Max. 20000
20000<
Scaled Min. 0
0<
Scaled Max. 16383
16383<
Output N18:124
7348<

0033

USED FOR DRYER OUTLET TEMP. FOR HMI

SCP
Scale w/Parameters
Input N18:124
7548<
Input Min. 0.0
0.0<
Input Max. 16383.0
16383.0<
Scaled Min. 0.0
0.0<
Scaled Max. 150.0
150.0<
Output F19:2
68.89764<

0034

LINE-02 MOISTURE PID AUTO/ MANUAL
N24:110
1

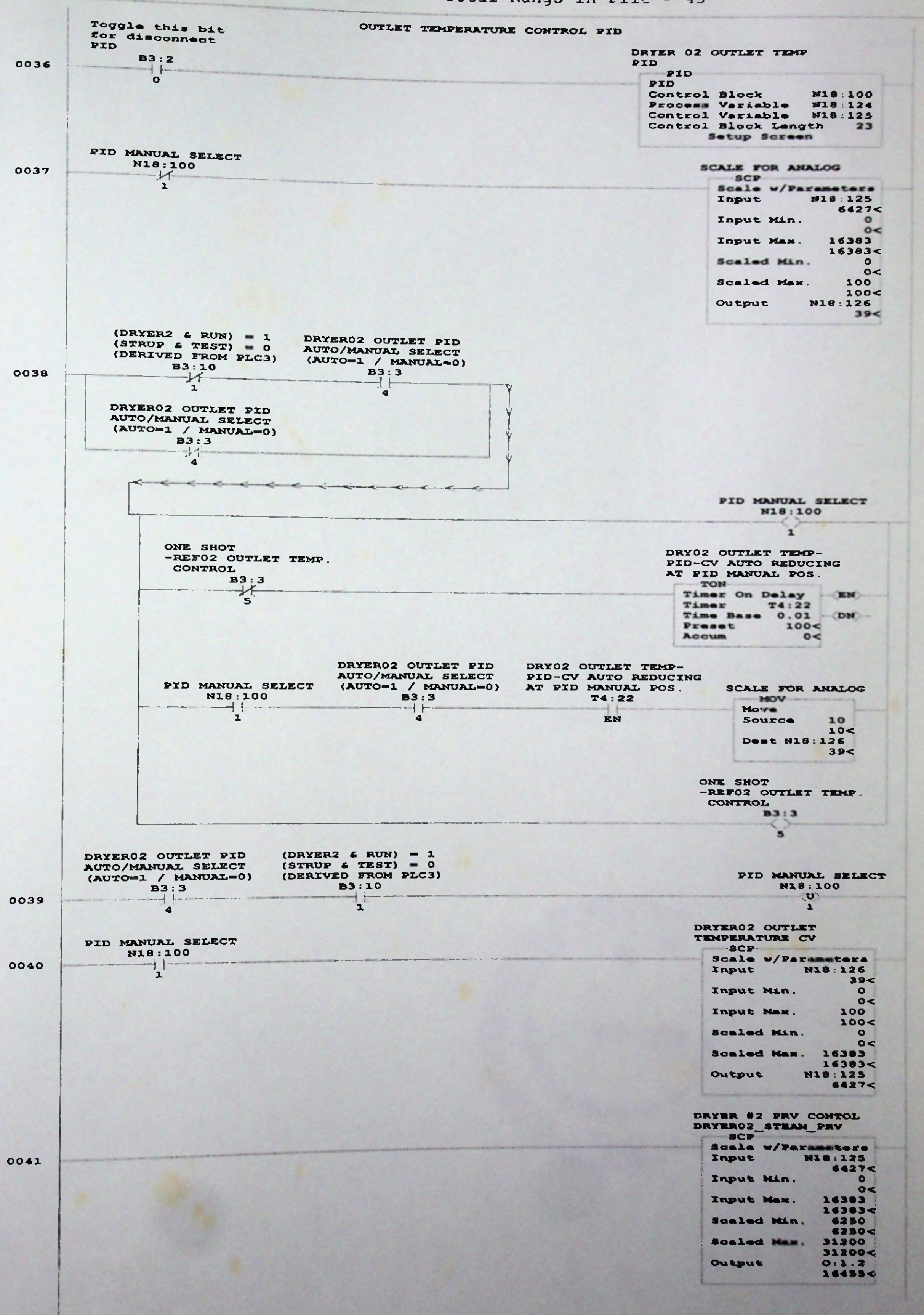
DRYER OUTLET TEMP. SETPOINT FROM HMI

MOV
Move
Source F21:17
65.99524<
Dest F19:13
65.99524<

0035

OUTLET SETPOINT FROM HMI

CPT
Compute
Dest N18:102
660<
Expression F19:13 * 10.0


Toggle this bit
for disconnect
PID
OUTLET TEMPERATURE CONTROL PID
0036
B3:2
0
DRYER 02 OUTLET TEMP
PID
PID
PID
Control Block N18:100
Process Variable N18:124
Control Variable N18:125
Control Block Length 23
Setup Screen
0037
PID MANUAL SELECT
N18:100
1
SCALE FOR ANALOG
SCP
Scale w/Parameters
Input N18:125
6427<
Input Min. 0
0<
Input Max. 16383
16383<
Scaled Min. 0
0<
Scaled Max. 100
100<
Output N18:126
39<
0038
(DRYER2 & RUN) = 1
(STRUP & TEST) = 0
(DERIVED FROM PLC3)
B3:10
1
DRYER02 OUTLET PID
AUTO/MANUAL SELECT
(AUTO=1 / MANUAL=0)
B3:3
4
DRYER02 OUTLET PID
AUTO/MANUAL SELECT
(AUTO=1 / MANUAL=0)
B3:3
4
PID MANUAL SELECT
N18:100
1
ONE SHOT
-REF02 OUTLET TEMP.
CONTROL
B3:3
5
DRY02 OUTLET TEMP-
PID-CV AUTO REDUCING
AT PID MANUAL POS.
TON
Timer On Delay
Timer T4:22
Time Base 0.01
Preset 100<
Accum 0<
EN
DN
PID MANUAL SELECT
N18:100
1
DRYER02 OUTLET PID
AUTO/MANUAL SELECT
(AUTO=1 / MANUAL=0)
B3:3
4
DRY02 OUTLET TEMP-
PID-CV AUTO REDUCING
AT PID MANUAL POS.
T4:22
EN
SCALE FOR ANALOG
MOV
Move
Source 10
10<
Dest N18:126
39<
ONE SHOT
-REF02 OUTLET TEMP.
CONTROL
B3:3
5
0039
DRYER02 OUTLET PID
AUTO/MANUAL SELECT
(AUTO=1 / MANUAL=0)
B3:3
4
(DRYER2 & RUN) = 1
(STRUP & TEST) = 0
(DERIVED FROM PLC3)
B3:10
1
PID MANUAL SELECT
N18:100
U
1
0040
PID MANUAL SELECT
N18:100
1
DRYER02 OUTLET
TEMPERATURE CV
SCP
Scale w/Parameters
Input N18:126
39<
Input Min. 0
0<
Input Max. 100
100<
Scaled Min. 0
0<
Scaled Max. 16383
16383<
Output N18:125
6427<
0041
DRYER #2 PRV CONTOL
DRYER02_STEAM_PRV
SCP
Scale w/Parameters
Input N18:125
6427<
Input Min. 0
0<
Input Max. 16383
16383<
Scaled Min. 6250
6250<
Scaled Max. 31200
31200<
Output O:1.2
16455<

0042 END