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Research Article

Adaptive Control Based Electric Furnace Temperature Control Using Simulink

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Abstract

In this paper, we have overcome the main problem of thermal tempering manufacturing process for temperature control of glass tempering furnace. Conventional methods for glass tempering are proportional, integral, derivative & fuzzy PID is inefficient for adapting the environmental system disturbances. Hence, the efficiency of the furnace is improved by using Model Reference Adaptive Control. It also gets a good dynamic response. In this paper, we also implemented feedforward control using with MIT rule. These methods tackle the variation of process dynamics and improve efficiency. The electric furnace for the temperature control model is controlled adaptively based on MIT rule and simulated using MATLAB/SIMULINK.

1. INTRODUCTION

Nowadays, in any kind of industry you look into it often used for heat treatment is an electric furnace. Furnace not only have load disturbances but also an environmental changes cause difficulty in working a furnace with efficiency.

The electric furnace has a great temporal variability in terms of hysteresis, non-linearity and time compared to other temperature control system as seen in [1] in this case there is no issue of environmental disturbances. So, for this object, the fuzzy logic control is enough for temperature control. Where as in electric furnace along with the load disturbances and environmental variability is also considered because these environmental disturbances also may change the temperature of furnace as seen in this paper [2] and the results of use of this type of controller is not that efficient as seen in [3] it can be improved. Many cases of theoretical and engineering research have also confirmed this point [4] even different type of controller can't get efficient output [5], [6]. Earlier implementation of fuzzy logic control in the temperature control and PID temperature control applied but due to changing environmental condition over time that affect the system. Due to this type of problem, we implemented a model reference adaptive control to solve this type of environmental problem that affects the system.

So, as the author in [7] states that for any nonlinear type of systems adaptive type of controllers are more effective because this type of controllers are pro-active and sense the disturbance without occurring it. Where as in cascaded PID controllers as in [8] these type of controller are adjust the minimize the error after occurring to the system. Where master control calculates the error

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calculations by taking memory values and predicts the system disturbances and sends the adjusted control signal to controller to avoid system from disturbances [9].

MRAC was originally proposed to solve a problem in which the performance of continuous stir tank in [10] which gave an very good dynamic response with no overshoot. Specifications are given in terms of a reference model. This model tells how the process output ideally should respond to the command signal.

An adaptive controller has been defined as a controller with adjustable parameters and a mechanism for adjusting the parameters. The construction of an adaptive controller thus contains the following steps.

- Characterize the desired behavior of closed loop system.
- Determine a suitable control law with adjustable parameter.
- Find a mechanism for adjusting parameter.
- Implementing the control law.

In MRAC we have reference model of how process should be operate. We feed it in model block whenever the process starts the output of process is compared with model block the calculated difference in error is feed to the controller. Model Reference Adaptive Control is a kind of control used by a controller which adapt control system with process parameter which vary with time or uncertain. It is a type of control which senses the parameter changes in control system and calculates the adaption mechanism and sends the control signal to the controller. It is also known as pro-active controller.

2. LITERATURE SURVEY

The author showed [1] in this paper evaluates the performance of temperature control in rice cooking system using intelligent control known as fuxxy logic controller to meet the special limitation and requirement of system. This system estimates the temperature required to cook the rice for given amount of rice and water. Author carried out this experiment in MATLAB as there are no environmental disturbances in this system the controller used in this project was sufficient whereas in our project environmental disturbances are taken into consideration. So, this type of controller isn’t sufficient to efficient output.

The author in [6] Advances in Technology Innovation, In this paper author implements this project by using Arduino as an interface between MATLAB controller and furnace. Both are connected by using DAC card. LM35 sensor is used to measure the temperature of furnace. When we observed the results PI controller gives the poor results when compares to the MMRAC controller. PID controller has more oscillations which may damages the system efficiency & has settling time is more.

Author in [11]. In this paper author employed the MRAC model for cylinder tank system for both interacting & non-interacting system. And compared it with conventional PID controller which gives an unstable process variable compared to MRAC model. MRAC model works on the principle of set point tracking technique and adjustment parameter are fed to controller to keep the system stable.

Author as in reference [12] Xiao-lan states that in this paper author tries to solve the equipment occurred problem related to fail condition of AC in Variable Frequency Drive room to reboot after power interruption. It has both hardware and software design and by using the Fuzzy PID controller. And compared to conventional PID controller. We observed from the results that fuzzy PID ouput is a bit efficient than PID controller output. But the output obtained from fuzzy PID is acceptable but can be improved more to get the system more efficient.

Author as in reference [13] Stelin-Emilian oltean states that in this paper author studies about plasma nitriding technique is nothing but a surface treatment technique which is done by using dc current. This technique is done to surface to introduce nitrogen to crystalline lattice of material. Due to which the thermos resitant of surface will be increased and increase in tensile strength.in this simulation fuzzy controls the temperature of work piece in nitriding process. This process has non-linear & multivariable characteristics. By analyzing the results in this paper we observed that by using the fuzzy control process variable didn't occur overshoot and reaches setpoint. Only disadvantage is that process variable reaches the set point with some time delay.

The author in reference [14] states that in this paper author studies about temperature control in continuous stirred tank reactor. I t also deals with both PID, Model Reference Adaptive controller & self-tuning regulator. By observing the results the conventional PID has more oscillations and its unstable where has MRAC has fewer oscillations and less settling time and self -tuning regulator has minimum settling time. In MRAC the algorithm used is recursive least square algorithm. Self-tuning regulator gives significant response because design calculations are eliminated and only regulator parameters are updated directly.

Author in [15] states that this paper presents the Pneumatic valve bottle washer using MRAC. Because bottle washing is the main problem before filling it with any type of material. As the bottle washing process in industries have many other disturbances along with the water level for washing and many other compenents. So, MRAC type calculates the disturbances with memory values and minimize the error.

3. PROBLEM STATEMENT

Most of the previous researchers studied different techniques of control techniques like, PID, Fuzzy, Fuzzy-PID and SMC control system. Although these techniques operate well in single operating mode they cannot continuously adapt variation of condition in dynamic process of the system. When there is environmental change which affects the system it would be difficult to regulate the system and to solve problem. Thus, efficient controller that can operate over a varied range of operating condition and adjust the variation of system process is required. This research work proposed MRAC feed forward control to solve the drawback of the existing controller and to improve the performance of the system.

The temperature control of Furnace for tempering process is to increase a Glass characterizes like, safer stronger and heat resistant etc. Control of electric furnace temperature for glass tempering process is difficult task due to process variation of dynamic operation of the system.

4. RESEARCH QUESTION

Research studies shows that the current used most of the controllers are not efficient with change in environmental conditions around furnace. These controllers cannot adapt to environmental changes for a period of time. So, we are introducing model reference adaptive type of controller to furnace which can adapt to environmental changes efficiently and gives good dynamic response.

Q. How to control electric furnace by taking environmental changes into consideration?

5. METHODOLOGY

Figure 1, shows the block diagram of MRAC. In this project we implement Model Reference Adaptive control by using MIT rule. Basically MRAC works on the principle where controller compares the process variable with the reference model which we fed to the controller at the input side.

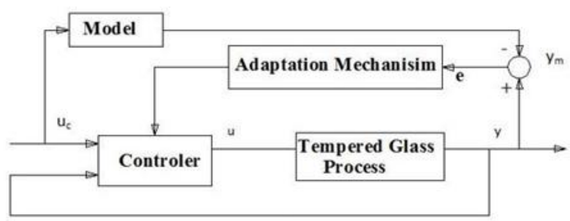

Figure 1. Block diagram of MRAC

As seen in above figure controller gets the input from 3 units one is a reference model which is standard and other is feedback from the tempered glass process and another is the output of adaption mechanism. Adaption mechanism is nothing but to adjust the parameter in control law. It is designed to attain stability of the system.

Figure 2, shows the block diagram of feedback with feedforward controller. In this paper we also implement MIT rule with feedforward PID controller. Which means both feedback and feedforward control are designed in parallel.

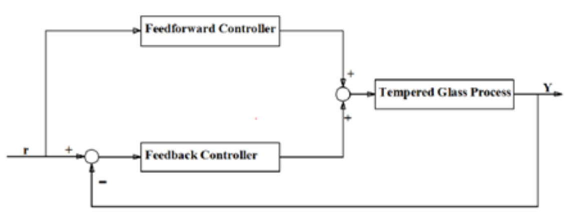

Figure 2. Block diagram of feedback with feedforward controller

4.1. Mathematical Modelling for Electric Furnace

Figure 3, shows the fundamental of electric furnace for glass tempering process.

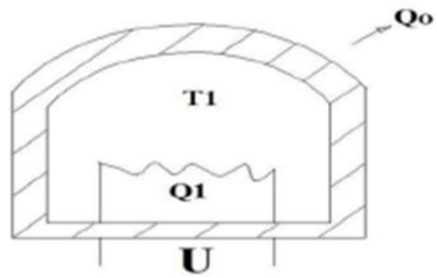

Figure 3. Electric furnace

Heat Flow Equation is given by
Qi = MC d (T_1 – T_0) + HA(T1− T0)…….. (4.1)
Where, Qi = Current Tempereature.
U = power supply.
H= Conduction coefficient.
C= Specific heat.
T1 = Current temperature.
T0 = Equilibrium Temperature.
A = Heat transfer area.
M = heating wire quality.

To determine the time constant, gain and the delay time by using the heat flow equation.
Q = H ÷ C_{pa} Pa (Th-Tl)…….. (4.2)
Where:
H is the amount flow (input power) in material M cal/hour,
Q is the flow rate of heat through the array of nozzles to glass surface by compressed air (radiation and convection)
Pa is density of air.
C_{pa} is the specific heat of air, M cal/deg.ton.
Th is heating temperature.
Tl is lower or room temperature.

Process parameters:
Volume of the furnace chamber is chosen to be V=4m^3.
Velocity of the glass is chosen to be = 0.133 m/sec .
Length of furnace =2m.
Cρ =0.2cal/gram℃.
P =2.5gram/ m3.
Electric power=120kw.
Then substituting in Eq. (4.2) gives Q=0.14m3/s.
Substitute the value of Q, V, ρ and Cρ I can get the constant value of
K=14, T=36sec, D=L =15sec.

The dynamic model of electric furnace of glass tempering process is:
G(s)=(ΔT(s))/(ΔU(s))=(Ke^(-Ds))/(Ts+1)=(14e^(-15s))/(36s+1)…….. (4.3)

The time delay cannot be represented by transfer function of dynamic model. Due to this, I can use Pade 1st order approximation using MATLAB to simplify the mathematical model. Equation we obtain after performing in matlab.

G(s) = (-14s+1.4)/ (36s^2+5.8s+0.1)…….. (4.4)

4.2. Adaptive & MIT Rule Modelling

The adaptive control law:

u (t) = $\theta 1 uc$(t) − θ2y(t)…….. (4.5)

Where:

u (t) is adaptive control,

θ1 and θ2 is adaptive control parameter,

y (t) is system output.

U(s) =Y(s)/G(s) = θ1 u (s) – θ2 Y(s).

From this, (Y(s))/(Uc(s))=(Y(s)-14s+1.4)/(36s^2+(5.8+ϴ2)s+0.1)

e = y – ym

E(s) = Y(s) − (s)

e(t) is the error between actual system output and reference model output.

e = (-14sϴ1+1.4ϴ1)/(36s^2+(5.8+ϴ2)s+0.1)

δe/ δθ1 = (-14sϴ1+1.4ϴ1)/(36s^2+(5.8+ϴ2)s+0.1)

δe/ δθ2 = (ϴ1(14s+1.4)(14s+1.4))/([36s^2+(5.8+ϴ2)s+0.1]^2)

MIT Rule

dθ/ dt=-γ δe/δθ

dθ1/dt=-γ (δe/$\delta\theta_1$) e= -γ_1 eGm (s)$_{Uc}$(s)

dθ2/dt=-γ(δe/$\delta\theta_2$) e= -γ_1 eG$_m$ (s)y(s)

6. SIMULATION

The following Simulink model is based on equation above. MIT rule is used to design a controller with Model Reference Adaptive Controller for any system. The following rule indicates how the error changing with repect to parameter θ.

Figure 4, shows the Simulink model of MIT. We need to provide a reference model which is given as 100/(s^2+20s+100) and transfer function of process is given as (0.389s+0.0389)/(s^2+0.161s+0.00278) by considering gains -10 and 10.

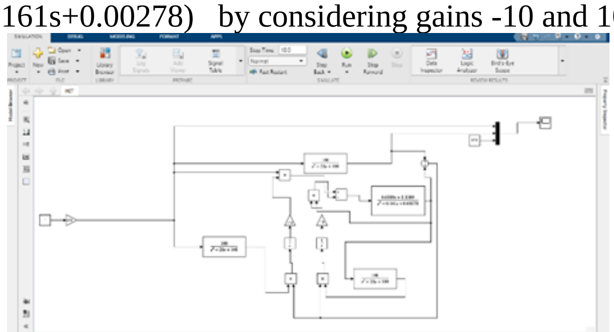

Figure 4. MIT Simulink block

Figure 5, shows the Simulink model of combination feedback and feedforward control for temperature control of electric furnace is designed. The well known time optimal control solution for a specific system will be derived by using Hurwitz row stability method. The optimal control of kf >= 2.42. The Simulink model for MIT rule with feedforward PID controller. The PID tuned values are taken as Kp = 0.131, Ki = 0.00176, Kd = -0.6815.

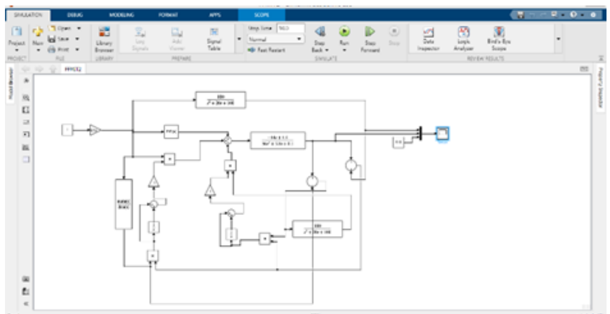

Figure 5. Feedforward using MIT

7. RESULTS

For a model reference adaptive control we need to provide a reference model of how the process should run According to which the controller minimizes the error signal even before occurring it.

Figure 6, shows the response of reference model graph shown is the result of reference model which is taken in this paper. Transfer function of reference model is 100/(s^2+20s+100).

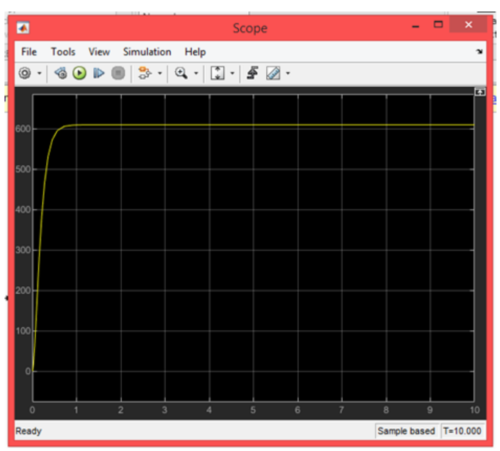

Figure 6. Response of Reference model

As we observed the results of fuzzy like controller implementation in which are not upto the the mark and unstability in process variable is observed due to external disturbances. Whereas in this reponse of MRAC with MIT rule you can observe there is no uncertainity in the process variable and the stability of the process is attained quickly without any overshoot.

Figure 7, shows the response of MIT rule as we observed in graph set point of model is fixed at 610 degree Celsius (Red line in figure). And process variable curve is as same as reference model graph. As observed in response there is no overshoot. And rise time is 0.213 sec and settling time is around 0.800 sec which is very efficient output.

Figure 7. Response of MIT rule

As we observed the results of cascaded PID in reference which gives response with overshoot and settling time is more compared to our result. Whereas in our response there is no overshoot occurred which means there is no chance of system unstability. The response of PID feedforward with MIT is similar to the response of reference model which gives us a dynamic response with stability.

Figure 8, shows the response of feedforward using MIT rule with PID controller is shown below in as we observed in graph set point of model is fixed at 610 degree Celsius (Red line in figure). And process variable curve is as same as reference model graph. As observed in response there is no overshoot. And rise time is 0.189 sec and settling time is around 0.769 sec which is very efficient output.

Figure 8. Response of feedforward using MIT

8. CONCLUSION

Reasearch question arised in this paper has been resolved. The observed results clearly shows the model reference adaptive type of controller are very efficient and gives dynamic response compared to the conventional controllers used earlier. The purpose of this paper has been to introduce the MIT rule adaption mechanism for temperature control of electric furnace. As observerd in the Figure 7 & 8 it is clear that process variable is dynamic and attains stability without any overshoot. Overshoot affects the process system and causes instability. As observed in Figure 7 & 8, the process variable follows the path of reference model as seen in Figure 6, without any deviation in path.

In earlier researches where the conventional controllers like PID, fuzzy-PID, etc., were used in process the process variable has overshoot and process variable and a slight oscillataion before it attains stability. In this paper the controller we used has no oscillation before attaining stability within below 1sec time.

The reasons for using adaptive control are: Variation in process dynamics, Engineering efficiency and ease of use, By studying the transient response of closed loop systems it is clear that MIT rule has more efficient and dynamic response than compared to any other conventional method like PLC, Fuzzy logic & Fuzzy PID. In this paper we have analyses temperature control of furnace with MIT rule and with combination of MIT rule with feedforward PID controller. As responses of these Simulink blocks observed that. Both these type of controllers are more efficient than any other conventional controllers which are been using in industries. It quickly adapts to environmental changes when compared to other controllers.

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