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REAL-TIME SYSTEM IDENTIFICATION OF THERMAL PROCESS

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ABSTRACT

Nowadays the presence of dead time in the process of Mechanical Industries leads to unsatisfactory performance. Dead time is one of the most important problems in the process industries. This dead time in each element of the process builds up and collectively causes many technical lags in the entire plant. In order to reduce these errors, suitable dead time compensators along with intelligent controllers should be used. Consequently, to design a suitable controller, a proper mathematical model of the plant should be found. This paper discusses about the real-time system identification of the thermal process using LabVIEW. Repeated tests were made at different conditions and using the average values the mathematical models for various regions were found.

Key words: Dead time, System Identification, Mathematical Model, LabVIEW.

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1. INTRODUCTION

The temperature control in industry is a crucial process. Temperature control decides the nature and rigidity of the material. The temperature being a slow process compared to other basic parameters in the industry such as pressure, flow and level. Control of temperature is an important role in the process control industries [2]. Any process or product manufactured can withstand only up to a certain degree of temperatures. If it exceeds that limit, it will lead to wastage or loss. For an instance in process industry, each product should be supposed to be maintained in certain temperature. If the control is not proper, the entire manufactured products will be wasted. Temperature is most important constraint to be focused seriously [1].

In this paper, the temperature process is chosen as the non-linear process which is to be controlled effectively. Temperature Process Station available in the Process control lab is considered for the proceeding the research.

2. PROCESS DESCRIPTION

The temperature process set up which is available in the lab is controlling the temperature of the outlet air which is blown out by the blower through the heating element shown in figure 1. The sensor used here to measure temperature is K-type thermocouple [3]. The range of K-Type thermocouple is –270 to $1260^{\circ}C$. The error detector circuitry finds the deviation between the actual temperature in the process and the set temperature. The control action is given to the power control circuit. The thyristor-based power regulatory circuit is formed by connecting the two silicon controlled rectifiers in the anti-parallel forms. The controller output is passed to the silicon-controlled rectifier, through a full wave rectifier after converting the ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage. Thus the Silicon controlled rectifier receives the positive gate pulses [7].

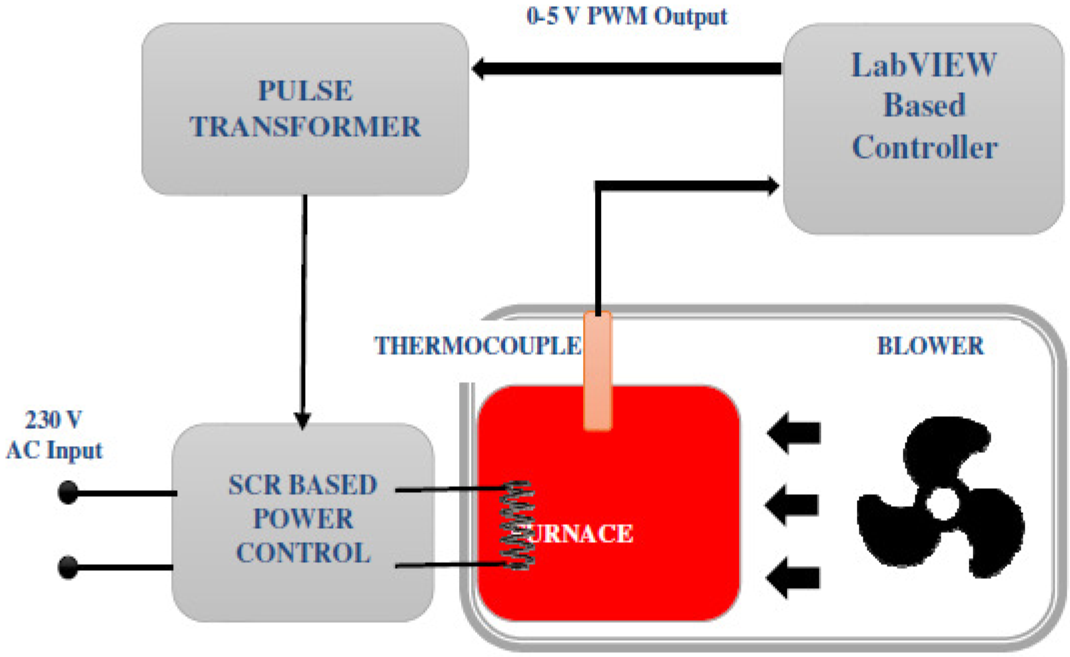

Figure 1. Block Diagram of the Temperature Process

The DC signal will be converted to ramp signal, which will be given to the op-amp as the inverting input [4]. According to the incoming voltages to the inverting output of the operational amplifier, this pulse width modulation circuit generates square pulse. Figure 1 shows the block diagram of the Temperature process. The following are the details of the elements of the temperature process.

2.1. Power Supply

The Furnace and the blower operate from an AC mains supply of 230V.

2.2. SCR based Power Control

Silicon Controlled Rectifier (SCR) is a unidirectional semiconductor device made of silicon which can be used to provide a selected power to the load by switching it ON for variable amount of time. These devices are solid-state equivalent of thyratrons and are hence referred to as thyristors or thyrode transistors.

2.3. Furnace

The inlet air to the process is been heated as it passes through heating filament. According to the required temperature of the outlet air, the filament is being heated with the help of the SCR based power control.

2.4. Blower

The fan moves the air axially, parallel to the revolving motor shaft. The air from outside due to low pressure get sucked inside and moves out after passing through the furnace. The blower is mainly used to quicken the process of heating by blowing air consistently. Even the same blower can be used for cooling purpose by turning off the furnace.

2.5. Pulse Transformer

Pulses are generated and transmitted by the transformer to the SCR based power supply. The tiny form signals are used in the digital domain and communication technology circuits, frequently for corresponding logic drivers to communication lines. Medium form signals are used in power regulatory circuits like camera flash controllers. Higher versions are used in the electrical power supply industry to communicate the low-voltage control circuit to the high-voltage gates of power semiconductors.

3. SYSTEM IDENTIFICATION

The main objective is to identify the model of the system, and to get the replica of the original plant. The empirical model is derived using the experimental data. The derived model is supposed to be solid, crisp and sufficient to serve the need it is to be used for. Table 1 shows the dissimilarities between physical and mathematical models.

Table 1 Difference between Physical Models and Mathematical Models

Physical Models	Mathematical Model
Microscopic	Macroscopic
Conservation law principles, physical properties	Experiments based: Test the system, search for similarities in the obtained data
PDE's: infinite dimensional	ODE's: finite dimension
Non-linear	LTI
No general-purpose technique	Standard techniques

Linear Time Invariant dynamic systems can be illustrated by means of a basic transfer function G that gives the relation between u and y which are the input and output respectively,

$$\frac{y(s)}{u(s)} = G(s) \quad (1)$$

This expression represents a continuous transfer function in complex s-plane. Since the models are mathematical, i.e the information about the physical condition is not needed [5]. The transfer function is used to illustrate the difference between mathematical and physical modelling of a single mass m that can move in a single direction x (output). A force (F - input) applied on the mass (m) to initiate the movement. Besides, the mass is attached to the spring with stiffness k, and a (viscous) damper (d). Thus the system transfer function is represented as

$$G(s) = \frac{x}{F} = \frac{1}{ms^2 + ds + k} \quad (2)$$

The constraints in this model indicate the physical properties of the given system. The model for System Identification is given as

$$G(s) = \frac{x}{F} = \frac{1}{ms^2 + ds + k} \quad (3)$$

$$G(s) = \frac{x}{F} = \frac{1}{s^2 + a_1 s + a_2} \quad (4)$$

From the above equation one can infer to select a second order model. The useful information of the system is obtained by experimentations. The system is given an input and the response of the system is noted for the given input [6].

A random binary signal is taken as input signal. In many cases the input and output signals are analyzed, the IDENT toolbox is referred in many cases. It also gives instructions on the procedures that are to be followed. A typical procedure for system identification includes:

- Selection of Input/ Output
- Design of Experiment
- Collection of Data
- Selection of Model Structure
- Estimation of Parameter
- Validation of the Model

4. REAL-TIME SYSTEM IDENTIFICATION

Depending on the observed and measured input and output information, the different methods of system identification can be used to build mathematical models of dynamic systems. The identification of mathematical model for a nonlinear dynamic system is as follows:

Initially the measurement of frequency response function is carried out, along with the features of nonlinear distortions and disturbing [8]. It utilizes very minimal user interaction as it adopts the nonparametric pre-processing technique. Considering this information, the user chooses based on objective, the modelling process, or to use a linear approximation framework which is simple or either to develop a nonlinear model. The following methods are explained here: a) Recognition of linear models amidst of error bounds and nonlinear distortions and b) Nonlinear model Recognition.

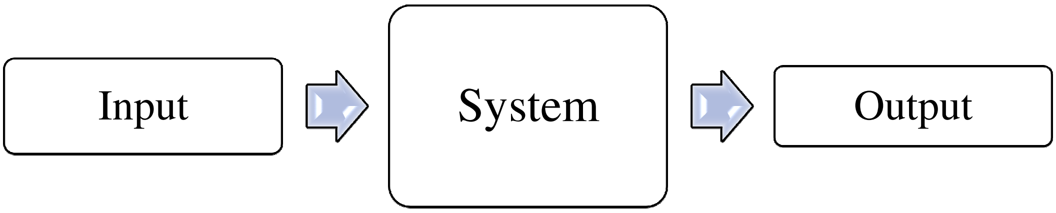

Figure 2. Block diagram of a system

The steps for identifying a system are given as follows:

- Analysis and Implementation
- Pre-processing of Information
- Selection of Model Configuration
- Estimation of Parameters
- Justification of the obtained Model

The following is the procedure for finding the mathematical model using the Process Reaction curve method:

- Change in process variable, ΔPV = Final steady state - Initial steady state
- 63% of PV = initial steady state of the process variable + 0.63(ΔPV)
- Determine the time taken by the process variable to cross the 63% of the process variable.
- Time taken by the process variable to give a clear response – step change in the controller output.
- Process time constant, Tp = Time taken to perform step 4 – step 3.

From the above steps process gain, time constant and the transport delay are determined to develop a mathematical model.

5. RESULTS AND DISCUSSIONS OF REAL TIME SYSTEM IDENTIFICATION

All these data are recorded in a spreadsheet to find the transfer function using the process reaction curve method [7]. Since this process is a thermal one, the system identification is done for more than 10 times and its average values are found. From those averaged values only the transfer functions are obtained for different regions. Figure 3 shows the block diagram for identifying the temperature process.

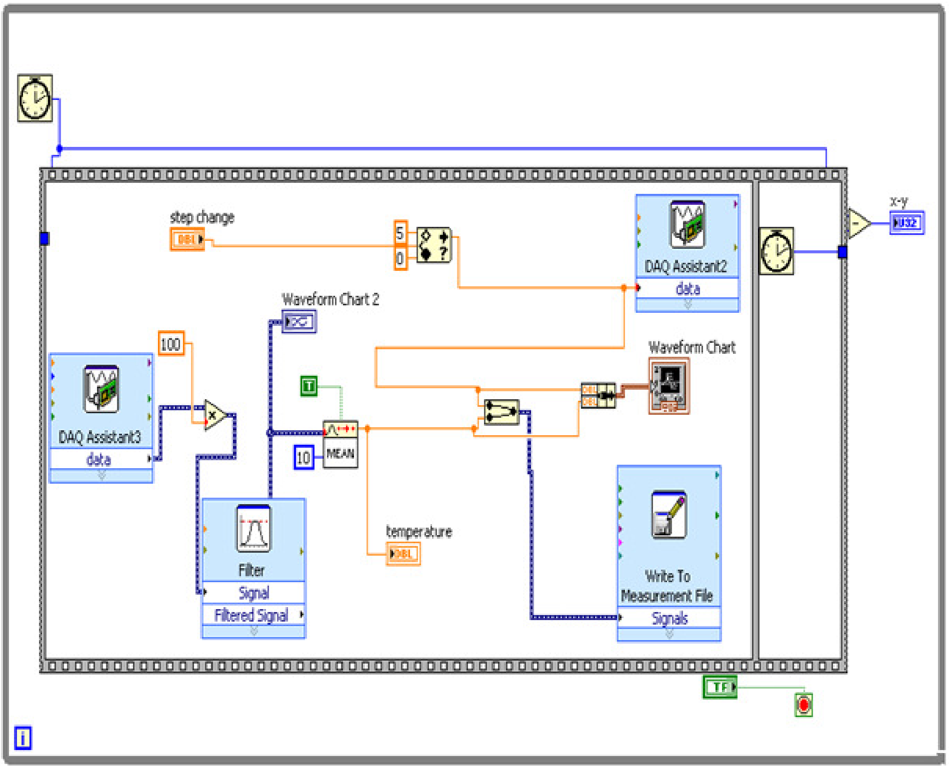

Figure 3. Block diagram for identifying the temperature process

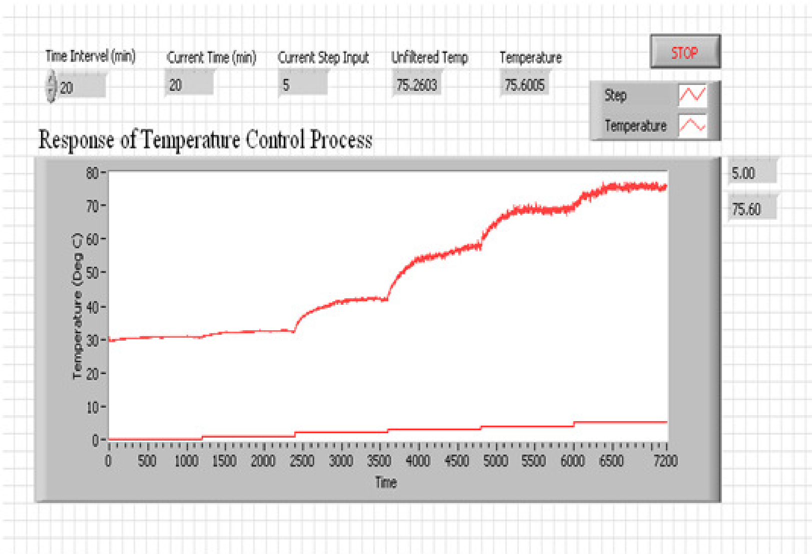

Figure 4. Front panel of the System Identification for various regions – Test 1

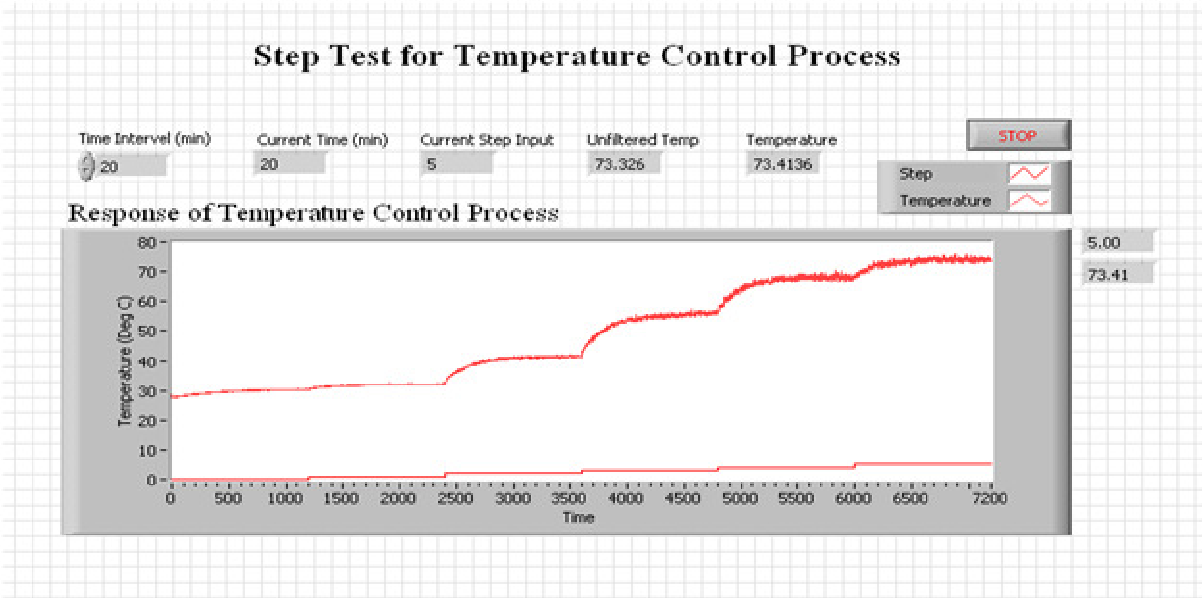

Figure 5. Front panel of the System Identification for various regions – Test 2

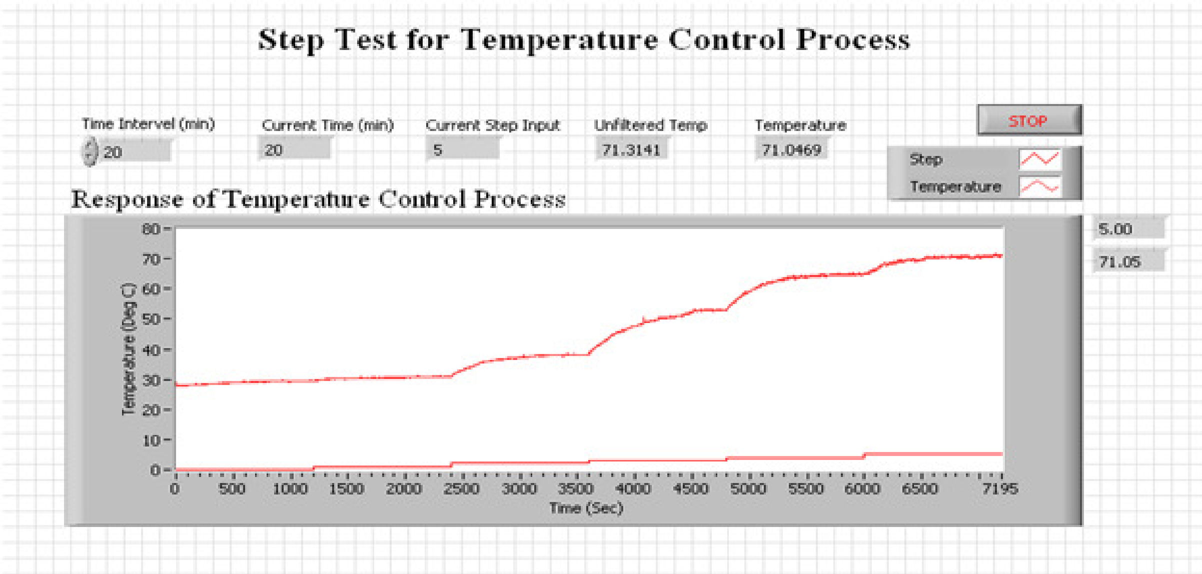

Figure 6. Front panel of the System Identification for various regions – Test 3

Figure 4, 5, 6 display the output response for five different regions of step inputs during various session of the test. It is clearly visible from the graph that for each region will have different transfer functions.

Table 2 Transfer Functions Obtained for Process using PRC Method

Voltage Range V	Temperature range °C	Transfer function
0-1	28-33	$\frac{1.654}{255s+1}e^{-2s}$
1-2	33-41.5	$\frac{9.385}{214s+1}e^{-3s}$
2-3	41.5-55	$\frac{13.8}{213s+1}e^{3s}$
3-4	55-68.5	$\frac{11.898}{217s+1}e^{-2s}$
4-5	68.5-74.5	$\frac{6.528}{184s-1}e^{-0.5s}$

Table 2 shows the obtained transfer functions or mathematical models for various regions for temperature process. The transfer functions obtained in table 2 are found from the average values of the test conducted at different instant of the time and climatic condition. From that the transfer functions of the thermal process has been obtained using Real-time identification technique using LabVIEW.

6. CONCLUSION

Process reaction curve method was used for finding the transfer functions for the various regions. The real time system identification method was done more than 10 times since the tests were carried out during different time period. Due to environmental condition, different readings were obtained and different transfer functions were obtained. Finally, average values were found to finalise the transfer functions for the different regions.

Real time system identification method is used to determine the mathematical model of the process. Step input was given to the temperature process and their transfer functions were obtained. Since the proposed process is the non-linear one, various step changes were given to the process such as 0-1 V, 1-2 V, 2-3 V, 3-4 V and 4-5 V [7]. Mathematical models were obtained for all the regions of step inputs.

Thermal process which is a slower one, can be controlled effectively only after designing the best controller. In order to design the best controller, the mathematical model close to the real process should be obtained. After validating the mathematical model with the real plant, best model can be identified for controller design. Then the design will be implemented in the real time.

REFERENCES

[1] Åström, K. J., &Hägglund, T. (2001) “The future of PID control. Control” Engineering Practice, 9(11), 1163–1175.

[2] Bradley T. Burchett and Richard A. Layton (2005) “An Undergraduate System Identification Experiment”, American Control Conference.

[3] Curtis D. Johnson (2008) “Process Control Instrumentation Technology”, Eighth Edition, Pearson and Prentice Hall Publisher.

[4] Francesco Beneventi, Andrea Bartolini, Andrea Tilli, and Luca Benini, (2014) “An Effective Gray-Box Identification Procedure for Multicore Thermal Modelling”, IEEE Transactions on Computers 63 (5), 1097-1110.

[5] Hans Petter Halvorsen, (2013) “System Identification techniques using LabVIEW for Air Heating System”.

[6] J.H. Lee, H.J. Shin, S.J. Lee, S. Jung (2013) “Model identification and validation for a heating system using MATLAB system identification toolbox”, IOP Conf. Series: Materials Science and Engineering 51.

[7] L.D.Vijay Anand, P. Poongodi, J. Jayakumar, Hepsiba. D (2017) “Analyzing the effect of pre-heater in the temperature process”, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 11, November 2017, pp. 113–120.

[8] L. Ljung (1999) “System identification - Theory for the User”, Prentice-Hall, USA.

[9] Tomas McKelvey, Andrew Fleming S and Reza Moheimani, (2000) “Subspace based system identification for an acoustic enclosure”, IEEE International Conference on Control Applications, Anchorage, Alaska, USA.