Design and Development of Artificial Neural Network based Temperature Controlling of Injection Mould Machine

M.Manga Lakshmi, I.Srinu, Dr. K.Satyanarayana

Abstract—In general PID (proportional +integral +derivative) controllers are widely used in many industrial applications due to their simplicity and robustness. In this paper temperature control of Injection Mould Machine by using conventional PID controllers such as Ziegler's – Nichols, Pessen's &Tyreus – Luyben methods have been studied. From this study it has been found that the controller design using conventional PID controller may not satisfy required performance criteria such as delay time, rise time, settling time, peak over shoot. To overcome this difficulty in this paper a new PID controller is proposed using artificial neural network technique. The proposed ANN – PID controller design method is based on Tyreus – Luyben tuning algorithm for rejection of different disturbance. To validate the proposed method, temperature control of injection Mould Machine control system is considered and an intelligent PID controller is designed using Artificial Neural Networks. The designed intelligent PID controller is simulated under different disturbance using MATLAB/Simulink and results are successfully verified.

Index Terms— PID controller, Dynamic Performance Analysis, Injection Mould Machine tuning concepts, ANN PID controller.

1 Introduction

THE extrusion process is one of most important polymer processing techniques and is also based on number of other important processing technologies. Understanding physical mechanisms taking place inside the extruder, number of new developments are induced, such as barrier screws, mixing sections, grooved barrels etc. For the last few decades usage of polymer materials has increased greatly because of their formation into complex shapes, its light weight with tensile/impact /tear strengths, its resistance property to high temperature, high chemical resistance, high clarity, reprocessibility and low cost.The above reasons resulted in awakening of new industrial applications for polymer materials by enabling products to be more cost effective, flexible and efficient. The diversified industrial sectors like packaging, household, automotive, aerospace, marine, construction, electrical and electronic, medical applications uses extrusion process.Even though this extrusion process is having so many advantages, control and effective thermal monitoring still remains as an issue.

2 INJECTION MOULD MACHINE

Basically there are two types of polymer processing extruders known as continuous and batch extruders. Between these two extruders single screw continuous extruders are the widely used in the plastics industry. Fig.1 shows the basic components of single screw extruder. The main component of this extruder is screw and this screw has been divided into three main functional / geometrical zones (i.e. solids conveying, melting and metering) based on their primary operations. The hopper is used to feed the material into the machine and is conveyed through the screw by absorbing heat provided by the barrel heaters and through process mechanical work. Mostly, a molten flow of material is pressurised into the die which forms the material into the required shape [1-7].

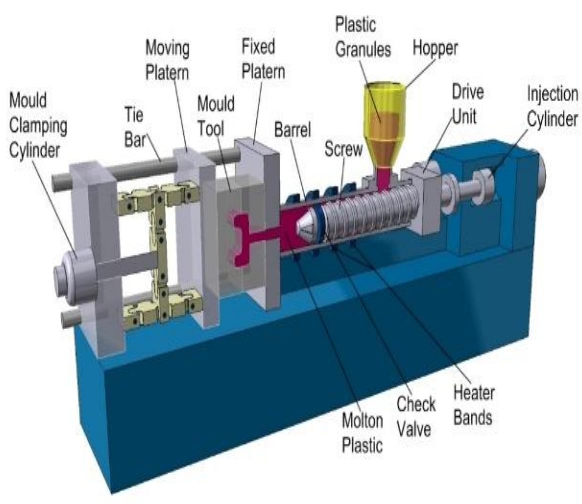

Fig. 1 Injection Mould Machine

Many things like wire spools, packaging, bottle caps, automotive dash boards, pocket combs, some musical instruments, one-piece chairs, small tables, storage containers, me-

This work was supported in part by the Electrical and Electronics Engineering Department, Pragati Engineering College (PEC).

- *M. Manga Lakshmi is currently pursuing masters degree in Power Electronics and Electric Drives in PEC(JNT University Kakinada, India, PH-9494657341. E-mail: mangalakshmi.ml@gmail.com*
- *I. Srinu is working as an Assistant Professor of EEE Department in PEC, India, PH-9963339708. E-mail: sreenuinjeti@gmail.com*
- *Dr. K. Satyanarayana working as Professor & HOD- EEE in PEC, India, PH-9000195104. E-mail: snkola@gmail.com*

chanical parts (including gears), and most other plastic products available today can be obtained by this injecttion mould machine. So in order to simulating these temperature characteristics, and to design proper controller, the injection Mould machine is modeled into a transfer function.

3 SYSTEM DESIGN WITH PID CONTROLLER

In temperature control system the temperature processing of a injection mould machine is a commonly controlled object. It can be given by the model shown in equation.

$$G(s) = \frac{K}{TS+1} e^{-\tau s} \quad \ldots\ldots. (1)$$

And now, for the given system the transfer function (2) can be given as [1],

$$G(s) = \frac{0.92}{144S+1} e^{-30s} \quad \ldots\ldots. (2)$$

Here,

Static gain (K) = 0.92

Time constant (T) = 144sec

Lag delay time (τ) = 30sec

A simple strategy widely used in industrial control is PID controller in Equation (3) shows the mathematical modeling of a general PID controller.

$$Y(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{de(t)}{dt} \ldots\ldots(3)$$

Here Y (t) = Control signal applied to the plant

K_P = Proportional Gain

T_I = Integral time

T_D = Derivative time

$K_I = \frac{K_P}{T_I}$ = Integral Gain

$K_D = K_P * T_D$ =Derivative Gain.

3.1 CLOSED LOOP/ULTIMATE CYCLE METHODS

Ultimate cycle methods are also called as closed loop/ ultimate gain methods. Those methods are discussed in this paper are as follows.

Ziegler's-Nichols [2] the first and foremost method in 1942. The advantage this method is quick and easier to use than other methods, it is robust, popular and moreover it is basis for all the improvements in the field of PID control tuning.

Pessen's based tuning method [3] is improved in 1954. This ultimate cycle method based on the consideration of the over shoot.

Tyreus-Luyben [4-6] quite similar to ZN method but final controller settings is different. These settings are based on ultimate gain & time period. By using these controller parameters are determined.

The generalized procedure for close loop methods:

Step-1: Simulate the temperature control of injection Mould machine control system using closed loop

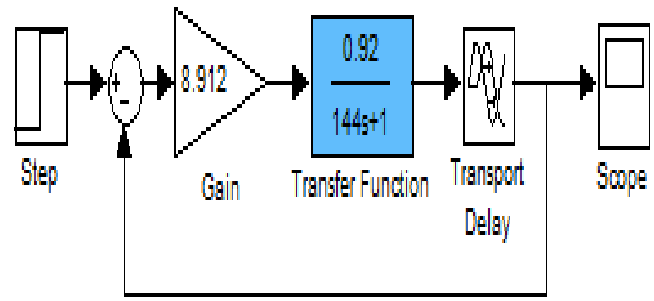

Fig. 2 Matlab/Simulink Model for Injection Mould Machine using ultimate cycle methods.

Step-2: Change the proportional gain value until the system exhibits the sustained oscillations.

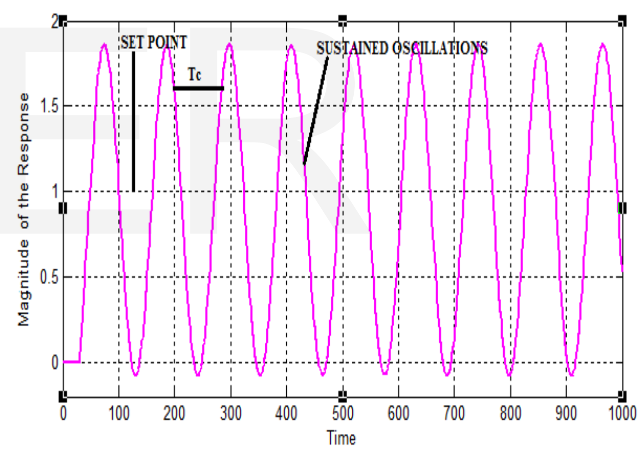

Fig. 3 Sustained oscillations for closed loop methods.

Step-3: This gain value represents in terms of critical gain (Kc) of the system. Note the time period of oscillations. This time represents the critical time period (Tc).

Step-4: Using Kc and Tc values, we calculate PID parameter gains based on tuning formula

$$K_P = 0.45 * K_C \ldots\ldots\ldots\ldots. (4)$$

$$T_I = 2.2 * T_c \ldots\ldots\ldots\ldots\ldots... (5)$$

$$T_D = \frac{T_C}{6.3} \quad \ldots\ldots\ldots\ldots\ldots. (6)$$

$$K_I = \frac{K_P}{T_I} \quad \ldots\ldots\ldots\ldots\ldots. (7)$$

$$K_D = K_P * T_D \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

These are the formulas for finding K_P, K_I, K_D values of Tyreus-Luyben method.

4 TEMPERATURE CONTROL OF INJECTION MOULD MACHINE BY USING ARTIFICIAL NEURAL NETWORK PID CONTROLLER

Artificial neural networks [8-14] are motivated by human way of learning and the network structure is motivated by human nervous system in the characteristics like learning for examples, fault tolerant, learns from experience, distributed in nature and etc. Neural networks have been successfully applied in the fields of load forecasting, pattern recognition, image processing, optimization and where the input output data is available. If spikes or transients are sufficiently involved in the trained data, then no doubt the neural networks will give accurate solutions. No mathematical calculations are required to train neural networks and to about results from trained neural network [9].

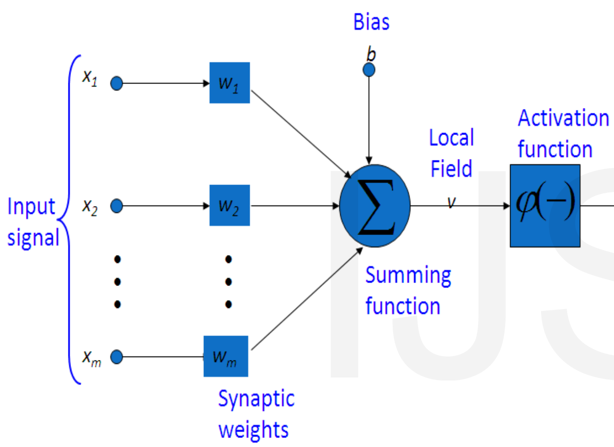

Fig. 4 Mathematical model of a neuron and feed-forward Neural Network.

Fig.4 shows the mathematical model of the neuron. x_1, x_2, x_3….. x_n are the scalar inputs and those are multiplied with synaptic weights w_1, w_2, w_3….w_n respectively and they are summed with bias (w_o). A bias is also like a synaptic weight with input signal one. The total sum is given as input to the activation function. Y is the output of the neuron. This is given by the equation.

$$y = f(p) = f[w_o + \sum_{i=1}^{n} w_i x_i] \text{……….(9)}$$

There are many activation functions used for the neurons. Of them, commonly used are linear, tan-sigmoidal and log-sigmoidal activation functions. Multi-layer feed forward neural network architecture is used in this paper because of its flexible characteristics.

In this paper tan-sigmoidal is used as activation function and back propagation is used as learning method. In multi-layer feed forward network appropriate input output and hidden layer neurons are used.

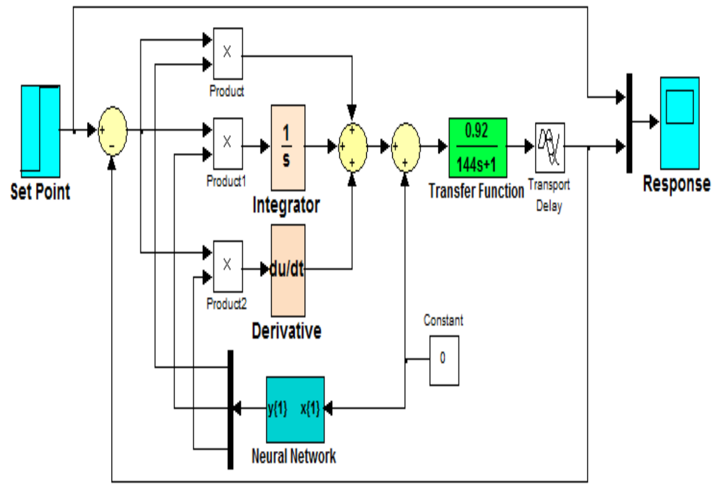

Fig. 5 MATLAB/Simulink model for temperature control of Injection Mould machine system with Artificial Neural Networks PID controller.

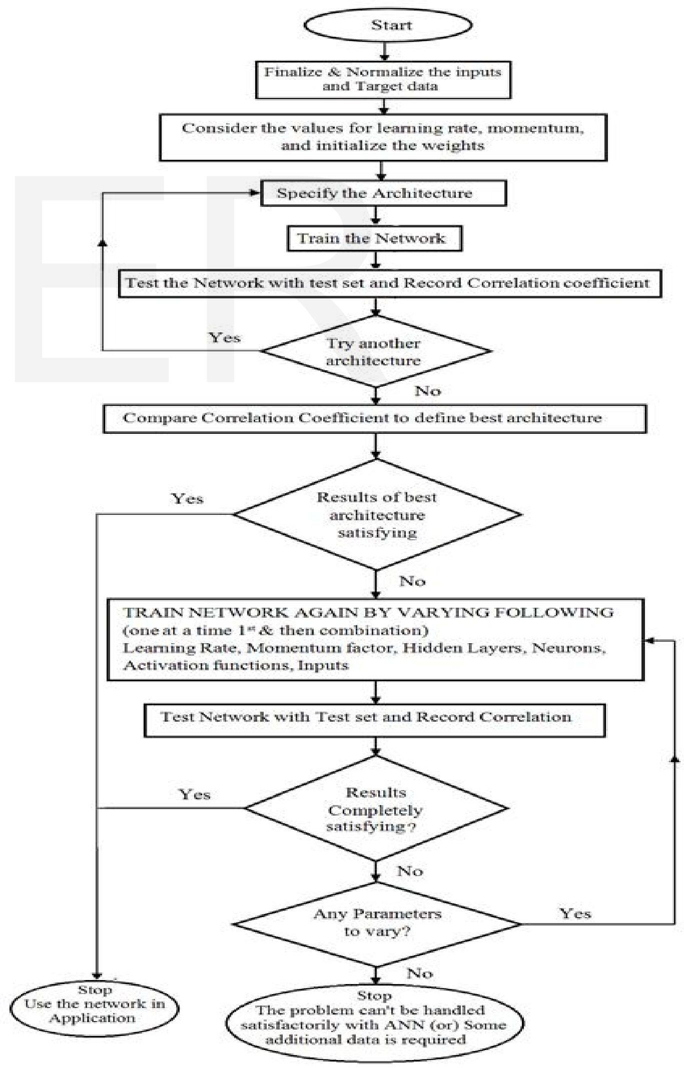

Fig. 6 Flow chart to design Artificial Neural Networks PID controller.

Initially disturbances are given to both the Injection mould machine as well as to the Artificial Neural Network (ANN). The gain values of Proportional (P) controller, Integral (I) controller and Derivate (D) controller are changed according to the different disturbances applied to the ANN. The weights in training algorithm are changed also according to the error which is produced from actual output and reference set point.The weights are changed by undergoing some iteration process. The gain value of the system is changed according to the disturbances by using Artificial Neural Network. Like this the system comes to stable state with in less time by applying Artificial Neural Networks PID controller.

5 SIMULATION RESULTS

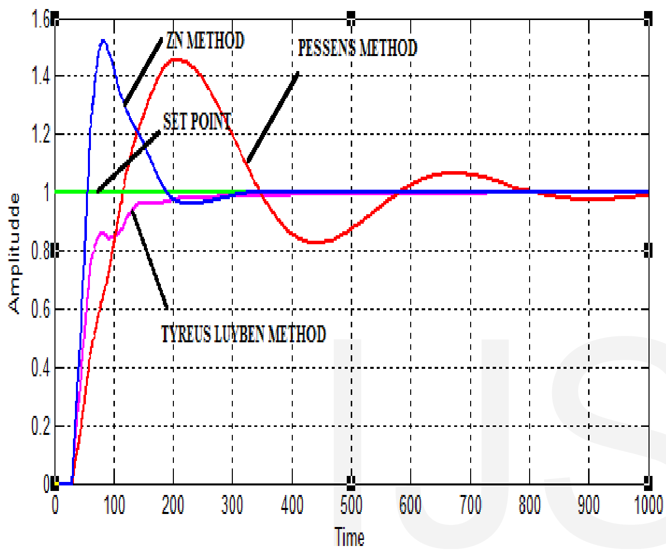

Fig. 7 Comparison of time responses of the system with ultimate cycle methods.

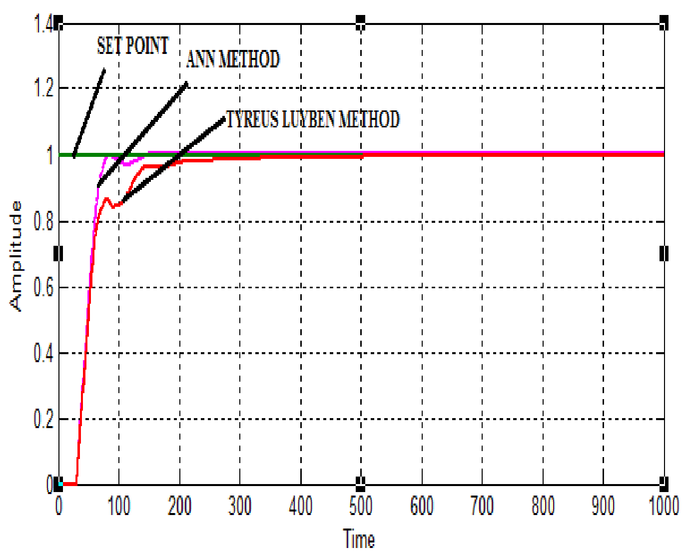

Fig. 8 Comparison of time responses with Tyreus-Luyben PID controller and ANN-PID controller without disturbance.

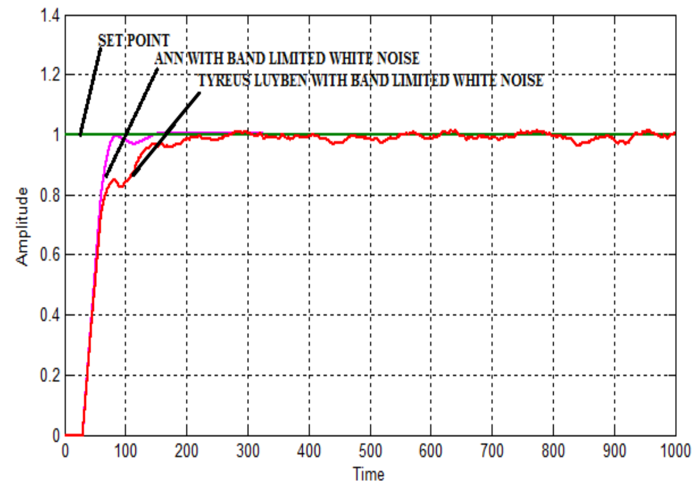

Fig. 9 Comparisons of Tyreus-Luyben with band limited white noise distur bance and ANN with band limited white noise disturbance

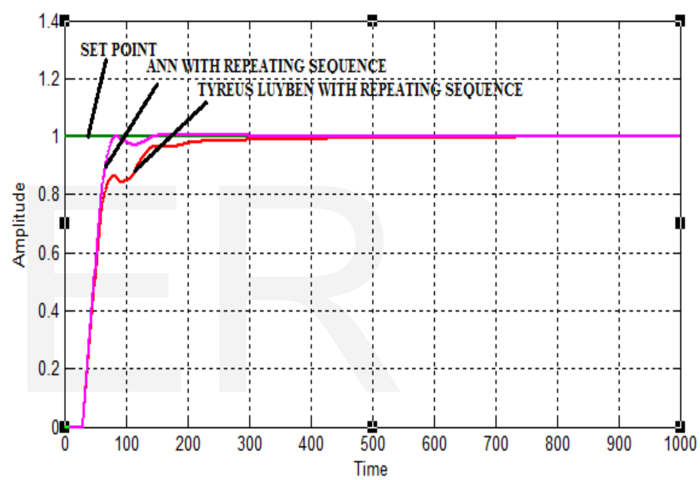

Fig. 10 Comparisons of Tyreus-Luyben with repeating sequence disturbance and ANN with repeating sequence disturbance.

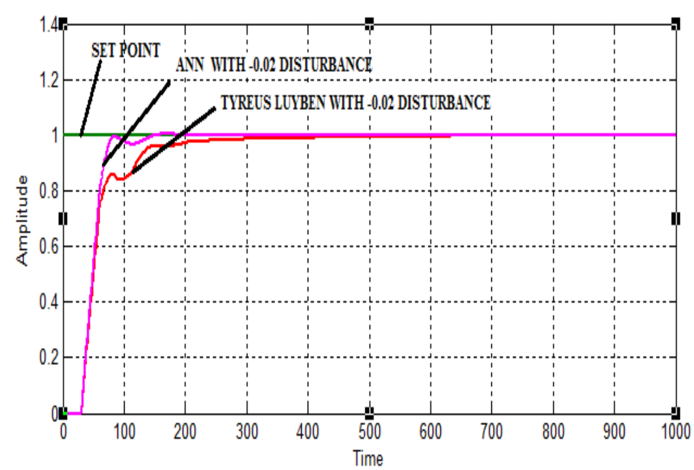

Fig. 11 Comparisons of Tyreus-Luyben with -0.02 disturbance and ANN with -0.02 disturbance.

TABLE 1
Time Domain specifications of system responses with various controllers with various disturbances

S. No.	Type of Disturbance	Dynamic Performance Specifications	Tyreus - Luyben PID Control	ANN-PID Control System	Improvement from Tyreus - Luyben PID to ANN-PID
1	No Disturbance	Delay Time (T_D) in Sec	50.13	48.71	1.42
		Rise Time (T_R) in Sec	85.01	33.77	51.24
		Settling Time (T_S) in Sec	135.74	72.54	63.2
		Peak Overshoot (M_P) in %	0	0	0
2	A Step Disturbance of '-0.02R'	Delay Time (T_D) in Sec	51.38	48.8	2.58
		Rise Time (T_R) in Sec	51.93	34.07	17.86
		Settling Time (T_S) in Sec	153.98	73.02	80.96
		Peak Overshoot (M_P) in %	0	0	0
3	A Step Disturbance of '+0.02R'	Delay Time (T_D) in Sec	51.14	48.62	2.52
		Rise Time (T_R) in Sec	50.55	33.45	17.1
		Settling Time (T_S) in Sec	151.75	72.05	79.7
		Peak Overshoot (M_P) in %	0	0	0
4	A Step Disturbance of '-0.04R'	Delay Time (T_D) in Sec	51.53	48.87	2.66
		Rise Time (T_R) in Sec	51.68	34.31	17.37
		Settling Time (T_S) in Sec	155.14	73.55	81.59
		Peak Overshoot (M_P) in %	0	0	0
5	A Step Disturbance of '+0.04R'	Delay Time (T_D) in Sec	51.02	48.55	2.47
		Rise Time (T_R) in Sec	49.9	33.66	16.24
		Settling Time (T_S) in Sec	150.66	71.62	79.04
		Peak Overshoot (M_P) in %	0	0	0
6	A Step Disturbance of '-0.05R'	Delay Time (T_D) in Sec	51.59	48.93	2.66
		Rise Time (T_R) in Sec	52.08	34.58	17.5
		Settling Time (T_S) in Sec	155.73	73.84	81.89
		Peak Overshoot (M_P) in %	0	0	0
7	A Step Disturbance of '0.05R'	Delay Time (T_D) in Sec	50.95	48.52	2.43
		Rise Time (T_R) in Sec	49.58	33	16.58
		Settling Time (T_S) in Sec	150.13	71.35	78.78
		Peak Overshoot (M_P) in %	0	0	0
8	Band Limited White Noise	Delay Time (T_D) in Sec	50.24	48.75	1.49
		Rise Time (T_R) in Sec	83.35	35.03	48.32
		Settling Time (T_S) in Sec	131.48	74.45	57.03
		Peak Overshoot (M_P) in %	0	0	0
9	Chirp Signal	Delay Time (T_D) in Sec	50.04	48.32	1.72
		Rise Time (T_R) in Sec	92.72	33.97	58.75
		Settling Time (T_S) in Sec	135.62	72.25	63.37
		Peak Overshoot (M_P) in %	0	0	0
10	Repeating Sequence	Delay Time (T_D) in Sec	49.58	48.46	1.09
		Rise Time (T_R) in Sec	86.96	33.32	48.58
		Settling Time (T_S) in Sec	133.18	71.94	61.26
		Peak Overshoot (M_P) in %	0	0	0
11	Repeating Sequence Stair	Delay Time (T_D) in Sec	51.25	48.71	2.54
		Rise Time (T_R) in Sec	51.23	33.77	17.46
		Settling Time (T_S) in Sec	152.85	72.54	80.31
		Peak Overshoot (M_P) in %	0	0	0

6 CONCLUSION

Hence, in this paper firstly, the conventional PID controller is used as temperature process controller for Injection Moulding Machine. Later on ANN PID controller is introduced for the same. The performance of both is evaluated against each other and from the table.1 the following parameters are observed.

1) In the case of Tyreus-Luyben PID Controller, the time domain specifications like Delay time, Rise time, Settling time and Peak over shoot are better in comparison with Ziegler-Nichols method and Pessen's method.
2) It is also observed that ANN-PID Controller suppresses the oscillations and operates the machine smoothly when compared with conventional Tyreus-Luyben PID controller.

Hence it is concluded that the ANN-PID controller gives better performance results rather than conventional PID controller in controlling of nonlinear parameters like temperature.

REFERNCES

[1] Hongfo Zhou, "Simulation on Temperature Fuzzy control in Injection Mould machine by simulink," Guagdong Provisional science and technology founding of China, 2007.
[2] Wolfgang Altman, "Practical Process Control for Engineers and Technicians," IDC Technologies, 2005.
[3] The Control Hand Book. CRC Press, 1999.
[4] Comparing PI tuning methods in a Real Bench mark Temperature control system by Finn Haugen.
[5] "Comparison of PID Controller Tuning Methods by Mohammad Shahrokhi and Alireza Zommorrodi, Chemical & Petroleum Engineering, Sharif University of Technology.
[6] Satish R. Vaishnav, Zafal, J. Khan; "Performance of tuned PID controller and a new hybrid fuzzy PD+I Controller," ACADAMIC World Journal of Modeling and Simlation, No. 2 Vol. 6, pp. 141-149.
[7] Dr. I. Santi Prabha, K. Durga Rao, "Fuzzy Logic Based Intelligent Controller Design for an Injection Mould Machine" (IJAEST) Vol. No.10, Issue No.1, 98-103.
[8] Jack M. Zurada, "An Introduction Artificial Neural Systems," wpc, 1992, ISBN 0-314-93391-3.
[9] Liu Luoren Luo Jinling "Research of PID Control Algorithm Based on Neural Network" Energy Drocidia13 (2011) 6988-6993.
[10] Yegna Narayana.B, "Artificial Neural Networks", Prentice Hall of India Pvt. Ltd, 2006.
[11] S. Rajasekharan, G.A. Vijayalakshmi Pai, "Neurla Network, Fuzzy Logic and Genetic Algorithms," Prentice-Hall of India Pvt. Ltd., 2006.
[12] Jyh-Shing Roger Jang "ANFIS: Adaptive- Networks-Based Fuzzy Inference System" IEEE Transactions on systems, man, and cybernetics, Vol. 23, No. 3, May-June 1993.
[13] Caminos P. and Munron N. PID controllers: recent tuning methods and design to specification, LEE Proceedings Control Theory and Applications, 2002, pp. 46-53.
[14] B Vasu murthy, Y.V Pavan Kumar U.V Ratna kumari "Fuzzy Logic Intelligent Controlling Concepts in Industrial Furnace Temperature Process Control" IEEE Transaction International Conference on advanced communication Control and Computing Technoliges ISBN NO.978-1-4673-2047-4, PP.382-387.